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OPTIMIZED LINEAR PROGRAM ANALYSIS OF THE EFFECT OF OXYGENATED FUELS ON CANADIAN OIL REFINERIES

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DISCLAIMER

This study was carried out with the cooperation of the Department of Energy, Mines and Resources. However, the views expressed in the report are those of the author and do not necessarily reflect the views of the Department.

Foreword

The purpose of this study is to assess the technical and financial impact of oxygenated gasolines on Canadian oil refineries. The study was carried out under contract by Hycarb Engineering Ltd., Calgary, Alberta. It encompasses a wide variety of oxygenates under different octane requirement scenarios, regions, and refinery types. Sensitivities to various blending octane values, volatility parameters, and capital costs were also explored. Although the impact of very low oil prices was not examined, the calculated breakeven values for the oxygenates should decrease proportionally. The supply costs of oxygenates manufactured from feedstocks with prices coupled to oil prices (eg. MTBE) should also decrease. Thus, the financial attractiveness of some of the oxygenates may remain relatively unchanged.

The financial attractiveness of oxygenates assessed in this study is based on numerous assumptions, and applies only to a hypothetical refinery. The results cannot be directly ascribed to any actual Canadian refinery. Undoubtedly, some refiners would find oxygenates more attractive than this study's hypothetical refiner and others would find them less attractive. Extreme caution should be exercised in interpreting the results of this study. The underlying assumptions and limitations should be thoroughly understood and taken into account.

Despite its limitations, this study fills an important information gap in the public domain and indicates that, under certain conditions, oxygenates can be financially attractive to refiners.

This study was restricted to technical and financial considerations from the refinery viewpoint. Costs and benefits on a national basis, and other considerations, are dealt with in the EMR Discussion Paper on Oxygenated Gasolines which should be read in conjunction with this study.

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GLOSSARY

UNITS AND TERMS

B	Barrel
°API	Degree API Gravity
°C	Degrees Celsius
FCC	Fluid Catalytic Cracking
FEVI	Front End Volatility Index
F.O.B.	Free on Board
gal.	Gallon
g	Grams
HFO	Heavy Fuel Oil
IBA	Isobutanol
IPA	Isopropanol
kg	kilogram
kta	Kilotonnes per annum
L	Litre
LFO	Light Fuel Oil
LP	Linear Program
LPG	Liquefied Petroleum Gas
M$/d	Thousands of Dollars Per Day
mg	Milligram
MON	Motor Octane Number
MMT	Methylcyclopentadienyl Manganese Tricarbonyl
Mn	Manganese
MTBE	Methyl Tertiary Butyl Ether
m^3	Cubic Metres
% Off	Percent Evaporated
Pb	Lead
psia	Pounds Per Square Inch Absolute
R+M/2	Octane (Research + Motor)/2
RON	Research Octane Number

GLOSSARY
(Continued)

UNITS AND TERMS (Cont'd)

RVP	Reid Vapour Pressure
TBA	Tertiary Butyl Alcohol
TEL	Tetra Ethyl Lead
% S	Weight Percent Sulphur
t	Tonne
ULR	Unleaded Regular (Gasoline)
USGC	U.S. Gulf Coast

ABBREVIATION OF NAMES

Alberta Gas Chemicals	Alberta Gas Chemicals Ltd.
Amoco	Amoco Oil Company
ARCO	ARCO Petroleum Products Company
Ashland Oil	Ashland Oil Inc.
ASTM	American Society for Testing Materials
BASF	BASF Canada Ltd.
Celanese	Celanese Canada Inc.
Chevron	Chevron USA, Inc.
Commercial Alcohols	Commercial Alcohols Ltd.
CGSB	Canadian Government Specifications Board
Diamond Shamrock	Diamond Shamrock Corporation
Dome	Dome Petroleum Ltd.
DSS	Department of Supply and Services
Du Pont	Du Pont de Nemours, E.I. & Co.
EMR	Energy, Mines and Resources
EPA	Environmental Protection Agency
Exxon	Exxon Company
Hycarb	Hycarb Engineering Ltd.
Mohawk	Mohawk Oil Co. Ltd.

GLOSSARY
(Continued)

ABBREVIATION OF NAMES (Cont'd)

Ocelot	Ocelot Chemicals
Petromont	Petromont Inc.
Phillips	Phillips Petroleum Company
Purvin & Gertz	Purvin & Gertz, Inc.
Saber	Saber Refining Company
Shell Chemical	Shell Canada Chemical Company
Sun (US)	Sun Refining and Marketing Co.
Sunoco	Sunoco Inc.
Texaco	Texaco Inc.
Trans Mountain	Trans Mountain Pipe Line Company Ltd.

I

INTRODUCTION

Alternative fuels are penetrating the traditional transportation fuel markets, and are being actively encouraged as substitutes for gasoline and/or gasoline blending components. The level of potential market penetration, and the impact on the refining industry, as the traditional supplier of gasoline, is uncertain.

The proportion of unleaded gasoline is increasing, and the lead content in gasoline will be reduced in Canada in January 1987. As a result, there will be a need for increased octane in the gasoline pool. There is a possibility of further reductions in lead and/or MMT content within a few years, thus increasing octane requirements further. Some refiners may require investments in new facilities. Alternatively, oxygenates such as alcohols or ethers, can be added to gasoline to increase octane.

When methanol is blended in gasoline, a higher alcohol is required as a cosolvent to enhance handling and driveability characteristics. In Canada, methanol supply far exceeds present demand, but cosolvents are not as readily available. To date, small-scale commercial operations have used ethanol and isobutanol (IBA) as cosolvents with methanol. Other possible cosolvents include isopropanol (IPA), and tertiary-butyl alcohol (TBA). An alternative to the direct use of methanol in gasoline is the use of methyl-tertiary-butyl-ether (MTBE) which is manufactured from methanol and isobutylene.

Many of the alternative oxygenates have other markets in the chemical industry. For each oxygenate, the production costs, market prices and producer margins vary. Since each oxygenate has different blending properties in gasoline, its value as a blending component will also vary. The effect of oxygenated fuels on refineries requires investigation.

Through the Department of Supply and Services (DSS), Energy, Mines and Resources (EMR) retained Hycarb to analyze the effect on refineries of using oxygenates in gasoline, using Hycarb's in-house refinery LP. Hycarb worked with its U.S. affiliate, Purvin & Gertz, to utilize their knowledge of oxygenated fuels in the U.S. and Europe.

The analysis compares the economics of oxygenate use against refinery operations with new investment and/or toluene purchase, if necessary. The major study parameters are as follows:

1. **Oxygenate** - Several blends of methanol and cosolvents as well as other oxygenates as follows:

   (a) Methanol/Ethanol - 5%/3%
   (b) Methanol/TBA - 4.75%/4.75%
   - 5%/3%
   - 7%/3%
   (c) Methanol/IPA - 4.75%/4.75%
   - 7%/3%
   (d) Methanol/IBA - 4.75%/4.75%
   - 7%/3%
   (e) Ethanol - 10%
   (f) MTBE - 11%

   A preliminary screening phase was used to select certain oxygenates for further analysis. This was completed in June, 1985.

2. **Gasoline Octane** - Several gasoline specifications (including lead levels) and grade splits, representing various octane requirements as follows:

   (a) current operations - 1985 market and actual lead levels (0.44 g Pb/L)
   (b) approved lead level (0.29 g Pb/L), with MMT, 70% unleaded gasoline
   (c) reduced lead level (0.027 g Pb/L), with MMT, 70% unleaded gasoline
   (d) reduced lead, with MMT, 90% unleaded gasoline
   (e) reduced lead, no MMT, 70% unleaded gasoline
   (f) reduced lead, no MMT, 90% unleaded gasoline

In addition, the significance of the octane blending number of an oxygenate on its refinery value was investigated.

3. **Gasoline Volatility** - Various volatility specifications were considered including:

   (a) average annual RVP, future distillation limits
   (b) summer RVP, distillation
   (c) winter RVP, distillation
   (d) use of a Front End Volatility Index (FEVI)
   (e) average annual RVP, current distillation limits

   In addition, the impact of blending volatility of methanol/ethanol on its refinery value was investigated.

4. **Refinery Technology** - The refining capabilities ranged from a typical catalytic cracking fuel products refinery to a hydrocracking/FCC refinery with aromatics production.

5. **Refining/Market Location** - The regions considered for this evaluation were:

   (a) British Columbia
   (b) Prairies
   (c) Ontario
   (d) Quebec
   (e) Atlantic

The study is based on typical refinery operations in each region with expected crude and product slates, and expected prices for crude and products. It includes future operating and capital costs where necessary. The economics of oxygenate use are developed for all five regions. Currency is in 1985, Canadian dollars, unless noted.

Refinery operations and economics with oxygenates are compared against a base case (without oxygenates). For each oxygenate case, the refined product slate is the same as in the corresponding base case, except for HFO and LPG. Crude and/or butane are reduced because of the purchase of oxygenate. The analysis includes the effect of oxygenates on crude oil and butane requirements.

The refinery values of oxygenates are determined based on changes in yields, capital, and operating costs from the base case. In addition, supply costs of oxygenate blends are estimated. These costs are compared with the refinery values to determine the margins available. An economic sensitivity analysis of selected cost components is provided. In addition to specific results for the typical refinery evaluations, the report provides a general interpretation of the results in terms of the overall refining/marketing industry, as well as the oxygenate industry in Canada.

II
SUMMARY

OXYGENATE MARKET

The projected demand for gasoline in Canada is 82,200 m^3/d in 1990, of which 57,600 m^3/d is unleaded regular gasoline. Oxygenate use could be as much as 11% or about 9,000 m^3/d.

Methanol consumption could be up to 7% of all gasoline or 5,800 m^3/d. Alternatively, MTBE would use methanol as feedstock, but methanol demand would be a maximum of 3,200 m^3/d. Existing methanol capacity which is surplus to Canada's current needs is estimated at 5,500 m^3/d. The use of methanol blends in gasoline would reduce but not likely eliminate the surplus.

Since there are no other oxygenates produced in Canada in significant quantities for fuel use, there is potential for new production of TBA, ethanol, or MTBE, particularly if the lead limit in gasoline is reduced to 0.027 g/L. There may also be potential for production and use of mixed alcohols from existing methanol plants.

OXYGENATE SUPPLY

On the supply side, methanol is available at a price around 72% of crude, or 61% of gasoline. Cosolvents are not yet available in Canada in significant volumes for a large-scale methanol fuel program, but could be imported or manufactured in the future.

The supply of IBA and IPA has exceeded demand in Canada, so product has been exported. IBA has been used commercially in gasoline in Canada as a cosolvent, but the existing IBA plant is closing down in early 1986. The chemical price of IPA exceeds refinery values. Since IPA would have to be supplied at near marginal costs to meet fuel values, the potential for IPA to serve fuel needs is limited to incremental supply from existing plants.

A small amount of fuel ethanol is used in Canada in gasohol and 5% methanol/3% ethanol blends. Methanol/ethanol blends could be economically attractive in the long-term, if ethanol can be produced from new facilities or imported at the present cost of foreign supplies from Latin America. In the short-term, ethanol appears to be the most likely cosolvent to introduce methanol blends on a large-scale, since it is available offshore.

TBA is not available in Canada, so would have to be imported from the USGC at present. In the long-term, it could be produced from isobutane. At estimated isobutane costs, the TBA production costs may be justified, once the lead limit is reduced to the approved level.

MTBE is not presently available in Canada, and would have to be imported from the USGC. It could be produced from isobutane and methanol in the future, and production costs could also be justified, especially in the Prairies. Although MTBE has higher value to refiners than most alcohols, its production cost is also higher.

BLENDING PROPERTIES

To carry out the analysis, blending properties (octane, vapour pressure and distillation) of each alcohol blend and MTBE were estimated. Among the alcohols, the lighter cosolvents (ethanol and IPA) have higher octane values than the higher alcohols (IBA and TBA), and octane values of alcohol blends increase with methanol content. However, vapour pressure also increases with methanol content, so less butane can be blended with gasoline. IPA blends have the lowest vapour pressure of the alcohols, whereas ethanol blends have the highest. MTBE has a lower octane value than most alcohols, but has a low vapour pressure, and so can allow more butane to be blended into gasoline.

Alcohols depress the boiling curve of gasoline base stock. The apparent % off of alcohols can be very high, exceeding 100%, especially for lighter alcohols such as methanol and ethanol. The high volatility of alcohols can cause problems for oxygenated gasoline in meeting volatility specifications.

The blending properties of oxygenates can vary for different gasoline base stocks. The sensitivity of results to blending properties have been evaluated. For specific applications, oxygenate blends should be tested with specific gasoline base stocks to determine correct blending properties.

REFINERY CHANGES

For 1985, the base case refinery used 0.44 g/L lead. New facilities were not required.

For 1990, with the approved lead specification of 0.29 g/L, the base case refineries required investment in new isomerization capacity, except in the Prairies, to increase the octane of light straight run naphtha for gasoline blending. Oxygenate addition eliminated the need for isomerization in Ontario, but not in Quebec.

For the 1990 reduced lead level of 0.027 g/L, the base case refineries required isomerization investments, and in many cases, major upgrading of catalytic reformers to increase severity. Oxygenates reduced the need for reformer revamps, but isomerization was still needed in most cases, except in the Prairies.

CRUDE/BUTANE BACKOUT

When an alcohol blend is purchased for addition to unleaded gasoline, butane use in gasoline is reduced to meet vapour pressure specifications, and so butane purchase is reduced. To balance the product slate, refinery gasoline base stock is also reduced. This requires rebalancing of refinery operations and allows a reduction in crude running. For the 5% methanol/3% ethanol, a highly volatile blend, butane purchase is reduced by 0.5-0.8 litre per litre. This blend also displaces 0.3-0.7 litre of crude per litre of oxygenate. MTBE, a low volatility component, reduces crude running by 1.1-1.4 litre per litre, but butane requirements are almost unchanged. Low vapour pressure components such as MTBE or toluene generally

have the highest value since they can displace crude oil rather than lower cost butane.

Future production of both MTBE and TBA on a large-scale would require isobutane feedstock. Overall, MTBE production increases butane demand, including refinery demand, by a volume equal to MTBE use. To produce TBA, isobutane feedstock requirements are approximately the same as the normal butane backed out of the refinery.

Across Canada, if oxygenate use reached 9,000 m^3/d, butane requirements could fall by as much as 6,000 m^3/d with 10% ethanol or increase by 9,500 m^3/d with 11% MTBE. Crude reduction could be as high as 13,000 m^3/d with MTBE.

OXYGENATE VALUES

Refinery breakeven values were determined based on a comparison of refinery operations with and without the oxygenates. Absolute values are found in the report, but are not given in the summary because of the multitude of cases evaluated. In this analysis, refinery values of oxygenates does not allow for possible additional downstream distribution costs for oxygenated gasoline.

With current and approved lead levels (0.29 g/L) in gasoline, oxygenate values in Ontario and British Columbia are above crude prices, but most are less than estimated gasoline prices. Under these lead specifications, oxygenate values in the Prairies, Quebec and the Atlantic are below crude prices. With reduced lead levels (0.027 g/L), oxygenate values vary according to other refinery conditions (eg. octane requirements, volatility constraints, technology), but the values of all oxygenates exceed crude prices, and many exceed the estimated gasoline prices in all regions of Canada.

The alcohols generally have similar refinery values because of their similar blending properties in gasoline. MTBE has a higher refinery value than alcohols because of its lower vapour pressure which results in negligible backout of butane and higher backout of crude oil.

The values of oxygenates are very much dependent on the refinery

environment. Some of the key factors that affect oxygenate values are summarized in this discussion.

Oxygenate values increase as octane requirements increase. Octane requirements increase as lead and MMT are reduced in gasoline, and the proportion of unleaded gasoline increases.

Oxygenates have higher values under summer operations than under winter conditions. Even though the allowable RVP is higher in winter, the addition of oxygenates in effect reduces the refinery gasoline/distillate ratio and the flexibility to produce the required product slate.

The distillation specification for gasoline potentially affects the value of oxygenates greatly. Proposed CGSB distillation specifications do not constrain the oxygenates. Current CGSB and ASTM distillation specifications reduce the value of highly volatile oxygenates, such as ethanol and 5% methanol/3% ethanol, because butane in gasoline must be reduced to the point that the oxygenated gasoline RVP is below the allowable maximum.

The introduction of an FEVI specification, which restricts both RVP and volatility, reduces the value of the highly volatile oxygenates (ethanol and methanol/ethanol), but has little effect on the value of methanol/TBA and MTBE.

There may be an optimum level of oxygenate addition below the maximum allowable. If an oxygenate is added to all grades of gasoline, its value is less than if it is added to only one grade because the incremental volume of oxygenate reduces refinery flexibility to reduce gasoline production from crude while maintaining distillate production.

Oxygenate value is dependent on the refining technology which is in place. For refineries which have high octane capabilities, oxygenate values are lower. Under approved lead conditions, oxygenate values are lower in a hydrocracking refinery than in a simple FCC refinery. However, under reduced lead conditions, the values of oxygenates are higher in the hydrocracking refinery, since oxygenates reduce catalytic reformer severity to a greater degree.

Oxygenate values are also dependent on location. Refinery values in Quebec and the Atlantic are lower than in Ontario under approved lead conditions, but similar to Ontario values under reduced lead conditions. In the Prairies, alcohol values are lower than in Ontario in both lead cases,

because alcohols back out less expensive butane. However, the MTBE value is higher in the Prairies under reduced lead conditions.

OXYGENATE ECONOMICS

In this study, the refinery breakeven values of oxygenates were compared with the estimated supply cost to determine a potential margin available to the refiner. This margin may be positive or negative.

The supply costs of methanol, TBA and MTBE are estimated to be lowest in the Prairies, based on production from low cost feedstock, and highest in the Atlantic. Ethanol supply cost is based on offshore deliveries, and is therefore estimated to be lowest in the Atlantic, and highest in the Prairies.

Other oxygenates, IPA and IBA, were considered only for Ontario. Based on refinery margins in Ontario, IBA and IPA appear to be uneconomic as cosolvents in oxygenated gasoline. They were eliminated from further study.

In the current market, with allowable lead content of 0.77 g/L and actual lead content of approximately 0.44 g/L, most oxygenates are not economic. An exception may be 5% methanol/3% ethanol, depending on the source and delivered cost of ethanol.

Under approved lead conditions (0.29 g/L) after 1987, methanol/ethanol and methanol/TBA should be economic in FCC refineries in Ontario and British Columbia. Methanol/TBA and MTBE should be economic in the Prairies if they are manufactured from low cost feedstock. None of the oxygenates appear to be economic in Quebec, Atlantic or hydrocracking refineries in Ontario. Ethanol (10%) is not economic in any region at the estimated supply costs.

Under reduced lead conditions (0.027 g/L), a wide number of refinery conditions and locations were evaluated. With MMT allowed in unleaded gasoline, and with oxygenates added to all gasoline grades, methanol/TBA (5%/3%) should be economic in all regions of Canada, except the Prairies. MTBE should be economic in the Prairies. Ethanol (10%) is not economic at the supply costs estimated for any region.

The above economics are sensitive to refinery product slates and product specifications. They are based on refinery operations under proposed CGSB specification for gasoline distillation. With MMT allowed in unleaded gasoline and with current CGSB and ASTM specifications for gasoline distillation, methanol/ethanol economics are uneconomic or marginal. Oxygenate values and therefore refinery margins are higher in summer and lower in winter. With MMT allowed in unleaded gasoline, most oxygenates will likely be uneconomic in winter.

If the FEVI specification is imposed, the value of methanol/ ethanol (5%/3%) will be reduced, but the blend should remain economic under refinery conditions and locations where it was considered economic without the FEVI specification. The FEVI specification will have very little impact on other oxygenates which were considered economic.

If MMT is eliminated from gasoline, all of the oxygenates except ethanol (10%) will likely be economic in all regions of Canada. Other considerations, such as volatility and technology, would not likely overcome the octane contribution of oxygenates if MMT is not allowed in unleaded gasoline.

The refinery valuation of oxygenates in this study was based on a price of light crude at Edmonton of $\$207/m^3$. As crude prices fall, the refinery value of oxygenates should fall. For oxygenates derived from petroleum and natural gas, their supply costs should also fall, but the incentive for the refiner to purchase oxygenates would likely fall as well. For oxygenates derived from other sources (e.g. ethanol by fermentation), the refiner's incentive to purchase oxygenates may be eliminated. Conversely, if crude prices rise, the economics of oxygenates should improve.

III
METHODOLOGY

BACKGROUND

In Canada, the proportion of unleaded gasoline in the marketplace is increasing, and the use of lead in leaded gasoline will be reduced from present levels (approximately 0.44 g Pb/L) to less than 0.29 g Pb/L by January 1, 1987. Since TEL increases the octane number of hydrocarbons and unleaded gasoline base stock has higher octane number than leaded gasoline base stock, refineries will be required to increase the octane number of their gasoline pools.

Beyond 1987, there is some possibility that TEL will be removed from gasoline altogether, or reduced to 0.027 g Pb/L. Another octane enhancer, MMT (presently allowed in unleaded gasoline at less than 0.018 g Mn/L), may be also be removed. These developments would increase refinery octane requirements still further.

Except for additives such as TEL and MMT, refiners have traditionally produced their own gasoline components, and finished gasoline within the refinery. Some refiners may be equipped already to increase the octane of the gasoline pool, while others may be forced to invest in new facilities, or to purchase other octane enhancers such as toluene or oxygenates.

Many options for facility changes are available to refiners to increase octane. The application and feasibility depend on specific refinery circumstances. Two of the more common options are to increase reformer severity, and to install an isomerization unit for light straight run naphtha (pentanes/hexanes) from crude oil.

APPROACH

The use of oxygenated fuels in gasoline has a complex effect on the petroleum refineries as they not only affect gasoline blending, but refinery operations and feedstock requirements (crude and butane). Each oxygenate has unique gasoline blending characteristics, and interacts differently at each refinery depending on the quality of gasoline base stock.

A rigorous analysis of the effect of the oxygenates would require a refinery by refinery analysis which is beyond the scope of this study. A simplified approach was necessary to evaluate the effect on the overall industry. For each refining region, a "typical" refinery has been selected as a basis. Using this approach, the magnitude of changes at the refineries can be determined; expected trends from using oxygenates can be established; and relative values of oxygenates at refineries as well as potential refiner margins can be estimated.

Each typical refinery is defined in terms of its process unit capacities and capabilities as well as its crude slate, and its yield and specifications of refined products. To establish the effect of oxygenated fuels, the refinery LP was used to first simulate this typical refinery for the defined base cases in which no oxygenates were used. Then the same refinery was simulated to incorporate the oxygenate in the specified gasoline blends. A comparison of the oxygenate case to the base case established the effect of the oxygenate on the refinery operation. The value of the oxygenate to the refinery was also determined in the comparison analysis. The relationship of this value to the estimated market price of the oxygenate defines the margin the refiner could expect when using the oxygenate in blending gasoline.

The Hycarb refinery LP model was used for the analysis, based on the following typical refinery data:

- unit yields and capacities,
- crude and product slates,
- product qualities,
- crude and product prices, and
- operating costs.

These data were generated for all refinery operations being considered. Constant 1985 dollars were used for all prices and costs.

The optimum refinery conditions for each case were determined using the LP model, based on specified crude and product slates as well as other defined constraints. Gasoline and distillate volumes from the refinery were held constant in relationship to the base case for all the

oxygenate cases. Refinery inputs and outputs that were allowed to vary included the following:

Inputs	Outputs
Crude Oil	LPG
Normal Butane	Butane
Isobutane	HFO
Natural Gas	Fuel Gas

Operating and incremental capital costs were generated for each case. If refinery production problems became apparent in any of the base cases, then the need for new or modified refinery facilities, such as isomerization or increased reforming severity, was investigated.

CASES ANALYZED

Based on all the study parameters listed in the Introduction, a great number of study cases were possible. The actual cases selected are shown in Table 1, and are numbered for reference purposes.

Cases I, II, and 1 in Ontario were carried out in the first phase of this analysis. This allowed a subsequent shortlisting of oxygenates, and provided an understanding of the significance of octane requirements due to lead phase downs. Case I represents current (1985) refinery operations. Case II represents 1990 operations at approved lead levels (0.29 g/L) with MMT allowed in unleaded gasoline. Case 1 represents possible future operations with reduced lead content (0.027 g/L) and no MMT. Subsequent oxygenate analysis was short listed to methanol blends with ethanol or TBA, as well as MTBE and ethanol. The preliminary analysis of these cases was based on current volatility (distillation) specifications of gasoline. This current analysis is based on proposed volatility specifications. This is discussed later.

Ontario was used as a basis for much of the study: to compare oxygenates, to evaluate octane (Cases I-5), and volatility (Cases 5-8). For these, a 16,000 m^3/d FCC fuel products refinery was used as a basis. To investigate technology, a hydrocracking/FCC refinery, producing fuel products as well as aromatic chemicals was used (Cases 9 and 10). The basis is discussed later.

Other refining regions were investigated. Cases selected for each region were restricted to: Case A (0.29 g Pb/L), comparable to Case II (Ontario); Case B (0.027 g Pb/L with MMT), comparable to Case 5 (Ontario); and Case C (summer product slate), comparable to Case 7 (Ontario). Oxygenates were restricted to MTBE, methanol/ethanol, and methanol/TBA.

British Columbia (Case 11) refinery operations were considered to be similar to Ontario operations, so British Columbia refining oxygenate economics were based on Ontario refinery operations with British Columbia prices and costs. Because of differences in gasoline grade splits with the approved lead level, one British Columbia model (Case 11A-1) was used to compare the Ontario and British Columbia results. The British Columbia results were then adjusted in the approved lead cases, based on the difference in these results.

Prairie refinery operations (Case 12) were considered unique, so were modeled as a regional FCC/hydrocracking refinery since some refineries have either FCC units or hydrocracking units. Prairie costs and prices are used for Prairie economics.

The Quebec refinery (Case 13) and the Atlantic refinery (Case 14) operations were considered similar in terms of process configuration as well as crude and product slate, so were modeled as one regional refinery. This is an FCC/hydrocracking refinery since several of the refineries in the region have both technologies. Oxygenate economics were developed separately for Quebec and the Atlantic, based on costs and prices in both regions.

IV
BASIS

REFINERY DEFINITION

Typical refineries were selected for use as the basis for this study. They are defined in Table 2 in terms of crude slate, product slate, and process unit capacities.

The refinery process units include atmospheric crude and vacuum distillation, FCC, hydrocracking, visbreaking, polymerization, alkylation, and catalytic reforming. A simplified flowsheet of a complex refinery is shown in Figure 1. The typical Ontario-FCC refinery includes only crude/vacuum distillation, FCC, alkylation, and catalytic reforming. In the hydrocracking refineries, the hydrocracker can use FCC feedstock and/or distillate product; hydrocracker products include middle distillates as well as light naphtha for gasoline blending and heavy naphtha which requires catalytic reforming. In the Quebec/Atlantic refinery model, polymerization is substituted for alkylation. The unit capacities for the typical refineries were developed by Hycarb and EMR.

The maximum average catalytic reformer severity has been estimated in the range of 93-94 RON for the Ontario-FCC and Quebec refineries. The maximum severity for the Ontario-Hydrocracking refinery is estimated at 96 RON because of aromatics production, and the Prairies' reformer severity is estimated at 97-98 RON maximum. Should any of the cases require a severity significantly higher than these, then some capital expenditure would be needed to meet the higher severity.

For 1990 cases, isomerization capacity was provided where necessary. The selected isomerization technology was for light straight run naphtha (pentanes and hexanes) with total recycle of normal paraffins. Feed desulphurization is necessary, but surplus reformer pretreater capacity can handle the isomerization feedstock. Isomerization was needed for all the base cases, except for 1985, Ontario (Case I), and approved leads on the Prairies (Case 12A). Many oxygenate cases required investment in new isomerization facilities as discussed later.

The crude and product slates in Table 2 were developed by Hycarb and EMR. These slates are considered representative for the regions that they represent. The crude slates in Ontario and the Prairies are predominantly light Alberta crude with some synthetic crude. The Quebec crude slate is about half light Alberta crude with the balance being imported medium crude, (32°API, 1% S).

Among the product slates, the gasoline grade splits vary depending on the lead scenario. With the approved lead level (0.29 g/L - Cases II, 9, 11A, 12A, and 13A), the proportion of leaded gasoline is higher, and the proportion of both unleaded grades is lower than in the reduced lead scenario. Other product slate changes are minor, and represent regional or seasonal effects; they are constant between base cases and oxygenate cases. All the product slates are restricted to conventional fuel products, except the Ontario hydrocracker cases which allow for production of aromatic chemicals. Optimum aromatics production levels were determined for the base cases, and aromatics were fixed at these levels when oxygenates were added.

GASOLINE QUALITY

Finished gasolines, with and without oxygenates, were blended to typical industry specifications as shown in Table 3. The minimum octane specifications are typical of industry standards and are more stringent than current CGSB requirements for octane. Specifications vary regionally because of altitude, and of course, among grades.

Volatility specifications (RVP and distillation) vary seasonally. CGSB standards are currently under review, and proposed RVP limits are higher by 0.5-0.6 psia. The CGSB and ASTM distillation specifications are defined by the boiling point at which a percentage evaporates, e.g. 50% off, see Table 3. Current CGSB specifications include only a maximum boiling point for 50% off, whereas ASTM specifications include both a maximum and minimum. Proposed CGSB specifications include both maximum and minimum boiling points. For LP simulation, the distillation specifications are converted to % off at a temperature, e.g. 70°C and 100°C. In the proposed

CGSB specifications, the minimum allowable boiling point at 50% off is lower than the ASTM specification, so the maximum allowable % off at 70°C is higher, especially in winter. Since oxygenates have low boiling points, the proposed CGSB specifications are less stringent with regard to oxygenates. The proposed CGSB specifications have been used as a basis for this work, although the impact of the distillation specification change is evaluated later.

The distillation (% off) specifications, along with RVP specifications control the volatility of gasoline. The introduction of an oxygenate into gasoline tends to depress the front-end distillation temperatures below those of the base gasoline. This results in the oxygenated gasoline blend having a higher percent vapourization at the lower temperatures (70-100°C). This results in a higher evaporative emission rate, and could possibly cause automobile driveability problems.

In one case (Case 6), a FEVI specification was introduced. This is defined as follows:

$$\text{FEVI} = \text{RVP (psia)} + 0.13\ (\%\ \text{off at } 70°\text{C}).$$

The maximum FEVI is 16.7 psia. For this case, the FEVI is imposed on the base case and the oxygenate cases. In addition to the FEVI specification, gasoline must still meet the individual RVP and % off specifications.

CRUDE AND PRODUCT PRICING

The crude oil price forecast for light Alberta crude oil at Montreal was provided by EMR. The 1990 forecast, in 1985$, is $\$215/m^3$ at Montreal. Based on this forecast Hycarb estimated prices of light crude at other Canadian refining centres. Prices are also needed for products where production is allowed to vary, such as HFO and LPG, and for other energy purchase streams such as natural gas, and butanes. These estimated prices are given in Table 4. Hycarb estimated product and butane prices are based on typical price relationships. EMR provided a gas price forecast

consistent with the crude forecast, from which gas prices at specific locations were estimated.

The ULR gasoline price is given for reference for oxygenate economics, and also for one Ontario case where extra gasoline production is allowed. The value of oxygenates are very dependent on the prices of crude oil and butanes since refinery consumption of these feedstocks is reduced by oxygenate addition. Therefore, the relative price of butane to crude is important. Normal butane price is approximately 72% of crude price at Sarnia, but only 59% at Edmonton. Isobutane price is estimated about 108% of normal butane price. Normal butane is normally used directly for gasoline blending, whereas, isobutane is required for alkylation feedstock. Isobutane can also be used to produce TBA or MTBE, as discussed later.

V

OXYGENATES

BLENDING PROPERTIES

Oxygenates exhibit different characteristics when blended into gasoline than they do as pure substance. Of particular interest in this analysis are the octane rating and vapour pressure. For example, pure methanol has a RVP of 5 psia and an average octane rating of 102 (R+M)/2. Yet, when it is blended into gasoline it exhibits an RVP of about 43 psia at a concentration of 10%. Its average octane blending value is about 116 (R+M)/2 in a gasoline blend. A similar pattern prevails for all of the oxygenates being evaluated. Also, the alcohols depress the boiling curve of the gasoline.

Table 5 presents the blending properties for octane, RVP, and % off for the oxygenates used in this study, as well as toluene and normal butane. These blending values were derived from published information plus data acquired through government and industry contacts.

The blending octanes shown in Table 5 represent typical values for the oxygenate since the actual blending octane is dependent on the specific gasoline blend stock into which the oxygenate is added. The blending octanes can vary as much as ± 8 octane numbers from those shown in Table 5 depending on the oxygenate and base gasoline stock used. In general, blending values appear to increase with decreasing octane number of the base stock and with decreasing concentrations of aromatics and olefins in the base stock. Thus, blending value is generally higher for regular gasoline than for premium gasoline. In leaded gasoline, some oxygenates exhibit positive lead susceptibility, and some exhibit negative susceptibility; i.e., the addition of lead to oxygenated gasoline may increase or decrease the octane, depending on the oxygenates used, see Table 5.

The blending vapour pressure of alcohol oxygenates is a non-linear function of the concentration of alcohol in the gasoline. Since MTBE is an ether rather than an alcohol it does not exhibit this characteristic. The

first increment of an alcohol sharply increases the vapour pressure of the gasoline blend, resulting in a high blending vapour pressure for the alcohol. However, subsequent additions of alcohol beyond 3% have little, if any, further effect on the gasoline blend vapour pressure. Consequently, the blending vapour pressure of the alcohol decreases as the concentration of the alcohol increases in the gasoline. As an example, three different concentrations of ethanol: 5%, 10%, and 15%, may each result in an increase of 0.7 psia in the blended gasoline vapour pressure. The calculated ethanol blending vapour pressure for the three concentrations are shown below:

Volume Percent Ethanol	RVP psia	
	Gasohol Blend	Ethanol (Calculated)
0	12.5	-
5	13.2	26.5
10	13.2	19.5
15	13.2	17.2

As noted earlier, alcohols in gasoline depress the boiling curve of the gasoline. For instance, if 10% ethanol were added to a gasoline base stock in which 30% is distilled at 70°C, the expected distillation would be 37% off at 70°C. However the measured distillation could be 42% off at 70°C. In this case, 10% ethanol causes an additional 5% to be evaporated, so the blending % off of the alcohol is 150%. The depression of the boiling curve is strongest with the lighter alcohols such as methanol and ethanol. This results in a higher % off blending number for lighter alcohols than for heavier alcohols, as shown in Table 5.

Among the alcohol blends in Table 5, the octane blending values are higher with lighter cosolvents such as ethanol and IPA, and increase with methanol concentration. IPA exhibits the lower RVP blending value. MTBE octane blending value is slightly lower than the alcohol blends, but its blending RVP is low. Components with RVP blending values above the gasoline specification will tend to backout butane whereas others will not.

Other properties are also important. TBA has a high freezing point (60-78°F), so has special handling problems, as discussed later.

Water tolerance is important to avoid phase separation with water present. The higher alcohols have higher water tolerance and could be blended in lower concentrations with methanol. For example, the proportion of TBA to methanol could be less than the proportion of ethanol to methanol. Water tolerance is also dependent on gasoline base stock quality, as water is more soluble in aromatics than paraffins. In this analysis, specific alcohol blends were selected, and the effect of water tolerance is not evaluated.

The alcohols, particularly methanol, have lower heating values per unit volume than normal petroleum gasoline components. The resulting blend could be 2-3% lower in heat content. This might cause specific fuel consumption (L/kilometre) to increase. However, the effect of alcohol heat content is partly offset by backing out butane which also has low heating value. The heating value of conventional gasoline probably varies more than 3% for different blends. Some argue that methanol blends can have higher thermal efficiency in automobile engines. The significance of alcohol heating value in gasoline is uncertain. One case has been analyzed assuming that ULR gasoline yield must increase by 3% to offset heating value.

MARKETS

The availability of the oxygenates to the refiner and the delivered cost at the refinery are major factors in the acceptance of the oxygenates as gasoline blending components. This section will briefly discuss the supply/demand situation for each of the oxygenates from a Canadian and U.S. standpoint. Foreign sources are also included if they have a potential impact on the Canadian market. Oxygenate pricing is addressed in 1985 dollars for both 1985 and 1990. Table 6 summarizes the estimated oxygenate prices in 1985 and 1990 in Sarnia and in other refining centres in 1990. The capital and production costs for IPA, TBA, and MTBE are given in Table 7.

METHANOL

Methanol has the potential of having the most significant impact on the use of oxygenates in gasoline blending due to the availability of supply and its current low price. However, the use of methanol as a blend component is somewhat restricted in that cosolvents (TBA, IPA, IBA, ethanol, etc.) are normally required to be blended with it. The availability of these cosolvents is an important parameter in the use of methanol.

Currently, methanol is in a worldwide oversupply situation with plants operating on an average of less than 75% of nameplate capacity. This has put a downward pressure on methanol prices, resulting in the lowest prices since 1978. While methanol demand is expected to increase through 1990, an additional 15,600 m^3/d of capacity is under construction in the Middle East, Far East, and Eastern Europe. This new capacity will result in supply capacity exceeding demand by over 20% in 1990. The continued oversupply situation will keep methanol prices in a depressed state, although some firming from the current level could be expected.

The U.S. methanol industry has been affected by this same oversupply situation. One result has been the shutdown of over 6,800 m^3/d of capacity in the last two years. This has resulted in a better balanced supply/demand condition. Current U.S. operating methanol capacity is about 12,600 m^3/d. Average U.S. demand is slightly over 13,700 m^3/d.

However, the reduction in U.S. overcapacity has been tempered by the rapidly increasing volume of methanol entering the country from abroad. In 1984, about 10% of the methanol demand was supplied by imports, and in 1985, it is expected to increase to approximately 20%. The rise in imports is a result of new methanol capacity coming onstream around the world, particularly in Saudi Arabia, which is satisfying demand in the Far East and Western Europe. Consequently, some Canadian product which traditionally supplied these areas, is now being imported to the U.S. Some methanol is also coming to the U.S. from Saudi Arabia and Trinidad. In the future, additional capacity will likely be shutdown in the U.S. and imports are expected to continue to penetrate the market.

The price of methanol in the U.S. has been depressed for the last few years, mirroring what has happened worldwide. Current methanol spot prices at the USGC are around 40¢(U.S.)/U.S. gal. This is well below the 1980 prices of about 60¢(U.S.)/U.S. gal. Prices are expected to firm somewhat this year. However, the worldwide oversupply situation will continue to keep pressure on the price of methanol and no significant increase is expected by 1990 in real terms.

In the U.S., the use of alcohol blends, including methanol in unleaded gasoline requires EPA authorization. Such authorization has been given for specific blends, including 4.75% methanol/4.75% TBA (Oxinol) and 5% methanol/2.5% ethanol (the DuPont waiver). Small volumes of Oxinol blend have been introduced commercially in the last few years, see TBA. The DuPont waiver was granted in 1985, but has not been used commercially.

In Canada, methanol is produced at three world scale plants located in Alberta (Alberta Gas Chemicals and Celanese) and British Columbia (Ocelot). Combined capacity is 6,300 m^3/d. Canadian demand for methanol is approximately 800 m^3/d. At full production, most of the production, 5,500 m^3/d, is exported to the Pacific Rim and U.S. markets. The typical Ontario refinery in this study could require up to 317 m^3/d methanol for 7% of ULR gasoline, well within the Canadian export levels.

Methanol is transported to the Ontario market by rail. Delivered cost in Ontario is estimated at about 18¢/L, with reported prices ranging from 16.8 to 22.4¢/L. Since worldwide methanol production capacity is expected to exceed demand into the 1990's, Canadian prices are not expected to strengthen. In fact, due to energy de-escalation, and currency exchange, the methanol price in Ontario in 1990 is estimated at 15.2¢/L (1985 dollars). The lowest price is 11.7¢/L in Edmonton, and the highest is 17.0¢/L in Halifax.

Methanol is now blended into unleaded gasoline in several provinces along with ethanol or IBA. This is discussed below.

ETHANOL

Ethanol is the highest volume oxygenate being blended into unleaded gasoline in the U.S. Over 5,000 m^3/d were blended into gasoline in 1984. Significant use of ethanol in gasoline began in 1979 as a result of the incentive provided by the National Energy Act of 1978. The Act suspended the 4¢(U.S.)/U.S. gal. motor fuel excise tax for gasohol (10% ethanol and 90% unleaded gasoline) blended using agricultural-based alcohol. The excise tax incentive has been increased to 6¢(U.S.)/U.S. gal. so that savings on gasohol equate to 60¢(U.S.)/U.S. gal. of ethanol. In addition, most states have enacted additional tax incentives ranging from 1¢ to 16¢(U.S.)/U.S. gal. of gasohol. With the availability of these tax incentives, ethanol use in gasoline has grown more than seven times since 1980. Gasohol volumes accounted for approximately 5.2% of the total 1984 U.S. gasoline demand of 1.0 million m^3/d.

The ultimate demand for ethanol in the U.S. will be closely tied to the continuation of the tax incentives and its use as a cosolvent with methanol under EPA waivers. The DuPont waiver allows a minimum of 2.5% cosolvent (ethanol, propanols, and/or butanols) to be blended with a maximum of 5% methanol in unleaded gasoline to a maximum limit of 3.7% oxygen by weight. The demand for ethanol as a gasoline blend component is expected to increase through 1990 because of octane requirements resulting from lead phasedown.

The current production capacity of fuel grade ethanol in the U.S. is estimated at 6,800 m^3/d. This capacity should continue to grow, possibly reaching the 11,000 m^3/d level by the late 1980's. Several refiners, including Ashland Oil, Chevron and Texaco are involved in joint venture ethanol projects.

Ethanol imports into the U.S. have risen significantly in the last few years, with Brazil being the major source of the imports. In 1984, an estimated 1,400 m^3/d of ethanol was imported into the U.S. for gasoline blending. The trend of increased imports of ethanol is expected to continue to 1990.

The price of fuel grade ethanol from fermentation distillation is primarily based on the cost of raw material and energy. Gasoline price and the tax incentives also have an effect on the ethanol price. The current price for ethanol in the U.S. Midwest ranges from $1.45 to $1.65(U.S.)/U.S. gal. depending on the producer and location. Imported ethanol from Brazil is being laid into the U.S. for about $0.80-1.00(U.S.)/U.S. gal. before tariffs or duties. The import duty on fuel grade ethanol is 60¢(U.S.)/U.S. gal. The future price of ethanol produced in the U.S. will still be influenced mainly by energy cost and grain prices, primarily corn. We expect that supplies of ethanol from Latin American countries will continue. Many ethanol projects, owned by government operations, are export oriented, and needed to support balance of payments, so product should be priced to sell in the large U.S. market.

In Canada, Mohawk produces up to 25 m^3/d fuel grade ethanol by fermentation in Manitoba. It is used in gasohol (10% ethanol in gasoline) and in a 5% methanol/3% ethanol blend in Saskatchewan, Alberta, and British Columbia. Some ethanol from the Commercial Alcohols, Montreal plant is also used for gasoline blends. This facility has capacity of 225 m^3/d of industrial grade ethanol from ethylene. Most is used for industrial solvents. About 120 m^3/d of industrial ethanol is exported. The typical Ontario FCC refinery in this study could use up to 453 m^3/d for 10% ethanol or 136 m^3/d for 3% in ULR gasoline. Clearly there is not enough fuel grade ethanol produced in Canada at present for significant use in gasoline blends. More ethanol might be produced by fermentation, or conversion of natural gas and methanol, but plans and economics are uncertain.

As discussed earlier, ethanol is being delivered to the U.S. market from Brazil at $0.80-1.00(U.S.)/U.S. gal. We have assumed that it could be delivered by ship to Sarnia for $1.00(U.S.)/U.S. gal. or 33.9¢ (Cdn.)/L. This assumes no import duty, as we understand that Commercial Alcohols had negotiated to eliminate the current duty of 7.7¢/L on imported crude ethanol when the shutdown of their ethylene supplier, Petromont, appeared imminent in late 1984. For 1990, estimated ethanol prices range from 31.2¢/L at Halifax to 35.0¢/L at Edmonton. The Vancouver ethanol price is assumed to be equivalent to a landed price of 33.0¢/L.

ISOPROPANOL

In the U.S., IPA is in an oversupply situation. Current production capacity is 4,100 m^3/d while demand in 1984 was estimated at only 2,200 m^3/d. Essentially, all the production went to the chemical market. Future demand growth for IPA in the chemical sector should be modest, at about 1% per year. Consequently, excess capacity will exist through 1990 and could be utilized for producing cosolvent IPA.

The current spot price for IPA on the USGC is $1.75(U.S.)/U.S. gal. This price is dictated by the chemical market. Only small quantities are used in gasoline blending mainly because of the high price. In 1990, the U.S. price should still be based on the chemical market since the high price will continue to discourage the use of IPA as a cosolvent with methanol.

In Canada, Shell Chemical at Sarnia has a 312 m^3/d IPA plant using propylene feedstock. Approximately half the production (125 m^3/d) is exported; mostly to the U.S. The typical Ontario FCC refinery in this study could require up to 215 m^3/d of IPA, for 4.75% in ULR gasoline.

Chemical prices in Sarnia for chemical grade IPA are approximately 62¢/L, including discounts. Since IPA is currently in surplus supply, we have estimated the 1985 price at 47.4¢/L, based on the USGC price of $1.75(U.S.)/U.S. gal. less transportation cost of 15¢(U.S.)/U.S. gal. and U.S. import duty of 20¢(U.S.)/U.S. gal. (14% ad valorem). However, we understand that supply of surplus IPA for fuel use, at appropriate fuel value, may be considered.

In the future, more IPA production facilities would be required to satisfy a larger market. For IPA pricing, we have assumed that a new 606 m^3/d plant would be constructed at Sarnia, and have estimated the IPA production cost in Table 7. Based on a propylene feedstock price at $440/t, the production case at Sarnia is estimated at 39.7¢/L, including capital recovery. Sufficient propylene should be available as feedstock, since more than 200 kta are exported, mostly from Sarnia. If not, supplemental

feedstock could be supplied by dehydrogenation of propane or import of propylene.

ISOBUTANOL

The current production capacity of IBA in the U.S. is approximately 330 m^3/d. In 1984, demand for IBA has been estimated at 250 m^3/d. The chemical market absorbs essentially all of the production. Only a small quantity appears to be available for cosolvent use either now or in the future.

A recent USGC spot price for IBA was $1.69(U.S.)/U.S. gal. This price is based on its use in the chemical market since little, if any, has been used in gasoline blending due to the high price. Significant use of IBA as a cosolvent with methanol will require new facilities to be built. It is unlikely that a large-scale plant could be installed, since IBA is a coproduct, and the increased market for 2-ethyl hexanol would not be available.

In Canada, BASF produces about 100 m^3/d of IBA in Quebec although a permanent closure has been announced for early 1986. IBA is a by-product from the oxo-synthesis of propylene to 2-ethyl hexanol. About 84 m^3/d of IBA is exported, mostly to Germany. The typical Ontario refinery in this study would require 215 m^3/d of IBA for 4.75% in ULR gasoline.

List price for IBA in Montreal is about 56¢/L. Since IBA is currently in excess of Canadian needs, we have estimated a lower price of 48¢/L, based on exporting to the USGC. The Sarnia price is based on delivery to the USGC at $1.69(U.S.)/U.S. gal. less 15¢(U.S.)/U.S. gal. transportation, and 12¢(U.S.)/U.S. gal. (8.8%) U.S. import duty. If the Canadian plant shuts down, the IBA price in Canada should be higher.

IBA is used commercially in gasoline blends in Germany. With extremely low gasoline prices in Europe at present, a netback price from gasoline use there would be much lower. We understand that supply of surplus IBA for fuel use, at appropriate fuel value, may be considered. IBA is

the cosolvent which has been used in most fleet test operations in Canada, and has been used commercially since 1985 in Ontario, where V-Plus (4.75% methanol/4.75% IBA) unleaded gasoline is available from Alberta Gas Chemicals and Sunoco.

TERTIARY BUTYL ALCOHOL

There is currently only one major producer of TBA in the world. ARCO has a 4,100 m^3/d plant on the USGC and a 1,600 m^3/d plant in Western Europe. The TBA produced at these plants is a by-product of propylene oxide, and the TBA production apparently can be reduced at full propylene oxide capacity.

ARCO has been actively promoting TBA in the U.S. as a cosolvent with methanol under a waiver by the U.S. EPA to blend methanol/TBA mixtures into unleaded gasoline. The maximum concentration is 4.75% methanol/4.75% TBA. The ratio of methanol to TBA cannot exceed 1 to 1.

In 1984, the estimated consumption in the U.S. of TBA as a cosolvent with methanol was about 750 m^3/d. Approximately 1,000 m^3/d was used to produce high purity TBA for the chemical market. Significant growth in the use of TBA as a cosolvent with methanol is expected in the U.S. for the future. The current TBA production capacity could handle a demand growth of about 15% per year to 1990.

TBA supply appears to be adequate for the introduction of TBA into the Canadian gasoline market. However, any significant growth in demand coupled with the expected U.S. increase in demand, will tax the supply of TBA before 1990. When the demand exceeds production capacity, then new capacity will be required.

ARCO currently does not post a price for gasoline grade TBA since its normal policy in the U.S. is to sell it in a mixture with methanol under the trademark of Oxinol. A recent spot price for Oxinol 50 (4.75% methanol/4.75% TBA) on the USGC was 66¢(U.S.)/U.S. gal., or about 1.0¢(U.S.)/U.S. gal. under the unleaded gasoline spot price. This equates to a TBA price of about 92¢(U.S.)/U.S. gal. based on the current methanol price. In

1990, the TBA price in the U.S. will depend on the level of demand for TBA and its value to a refiner or blender. If it is high enough to require that new production facilities be built, then the price will have to cover new plant production costs. Since the major market will be for fuel use, the TBA price will likely be tied to gasoline price.

There is no TBA production in Canada. The only TBA production in North America is at the USGC, as discussed previously. For Canadian use of TBA in the short-term, we have assumed that TBA would be imported at 41¢/L based on the USGC price of 92¢(U.S.)/U.S. gal. plus transportation of 17¢(U.S.)/U.S. gal. plus Canadian import duty of 12¢(U.S.)/U.S. gal. (13.1%).

For a long-term market, TBA would likely have to be produced from a new plant. TBA can be produced directly from isobutylene. There is very little surplus isobutylene available in Canada, so a large plant would require dehydrogenation of isobutane. At Sarnia, isobutane is available from field butanes, and from an isomerization plant at Dome. The Dome plant has 1,600 m^3/d capacity, and is often idle. TBA requires 1.23 litres isobutane per litre of product. We have assumed a new plant with capacity of 605 m^3/d TBA. Based on a feedstock price of 16.6¢/L for isobutane, we estimate the cost of TBA production, including capital recovery, around 32.1¢/L at Sarnia. The TBA production cost at Edmonton is estimated at 28.0¢/L with isobutane priced at 13.2¢/L.

TBA has a potential handling problem because of its high freezing point (60-78°F, depending on purity). A plant located at Sarnia may have to purchase methanol to preblend the alcohols for gasoline use. In the short-term, TBA imports, if available, might contain some methanol in order to suppress the freezing point.

METHYL-TERTIARY-BUTYL-ETHER

MTBE has been used as a blend component in gasoline in the U.S. since 1979 when the first MTBE plant was placed onstream. The current regulations allow approximately 11% MTBE to be blended into unleaded gasoline.

It is the only oxygenate that has been generally accepted for refinery blending and subsequent transport through pipelines. MTBE appears to be the most widely used oxygenate among the U.S. oil companies. For example, ARCO, Texaco, Exxon, Phillips, Amoco, Sun, Diamond Shamrock, and Sabre, all have built MTBE plants or have units in the planning stages.

The current U.S. MTBE operating capacity is approximately 4,100 m^3/d. Much of the capacity is captive and used by the individual oil companies for its own gasoline blending. A limited amount of merchant MTBE is available from several producers. Little, if any, is imported to the U.S. from Europe. Three new plants are in the planning stages and should be on stream before 1990. These plants will increase MTBE capacity to 4,700 m^3/d by 1990.

Outside the U.S., MTBE capacity currently onstream is about 3,300 m^3/d. There are a number of plants in the planning stages that could add as much as 10,000 m^3/d of capacity by 1990. A large new plant was recently announced for Saudi Arabia that would have a capacity of 1,900 m^3/d.

The current spot price on the USGC for available MTBE was 92¢(U.S.)/gal. The spot price for MTBE has shown a historical relationship with gasoline. On an average, it has sold for a 20% premium over the spot price of unleaded gasoline. In the future, MTBE available on the spot market should continue to be sold at this premium. If quantities are required that are greater than the merchant market, then new plants will need to be built to satisfy those demands. Production economics for a new plant could then affect the price of MTBE.

There is no MTBE production in Canada at present. The typical Ontario refinery in this study could require 418 m^3/d of MTBE for 11% concentration in ULR gasoline. For short-term use, MTBE would have to be imported. We have estimated a delivered cost of 40¢/L based on a USGC price of 92¢(U.S.)/U.S. gal. plus 15¢(U.S.)/U.S. gal. transportation and 12¢(U.S.)/U.S. gal. (13.1%) Canadian import duty.

For a long-term market, MTBE would likely have to be produced from a new plant. MTBE is produced from isobutylene and methanol. It may be

possible for an individual refinery to provide isobutylene for at least part of its requirements. For larger scale operations (1,020 m^3/d MTBE), isobutylene will have to be produced from isobutane, as for TBA production. MTBE feedstock requirements are 0.96 litres isobutane and 0.35 litres methanol per litre of product. Based on feedstock prices of 16.6¢/L for isobutane and 15.2¢/L for methanol, we estimate a production cost, including capital recovery, around 27.6¢/L at Sarnia. With lower feedstock costs at Edmonton (13.2¢/L for isobutane, and 11.7¢/L for methanol), MTBE production cost is estimated at 23.2¢/L.

VI

ECONOMIC ANALYSIS

REFINERY OPERATIONS

BASE CASE OPERATIONS

The first step in determining the effect of blending oxygenates in gasoline on refinery operations was to simulate the base case refinery operations (without oxygenates) using the LP. The results of the base case LP runs for most of the cases are summarized in Table 8. This table shows the input and product streams which were allowed to vary for oxygenate cases, as well as important refinery operations.

The base case results for the typical Ontario FCC refinery are summarized as follows:

BASE CASE OPERATIONS
(Ontario - FCC Refinery)

		1990 Approved Lead		1990 Reduced Lead	
	Case I 1985	Case II With Isomerization	Case II Without Isomerization	Case 5 With MMT	Case 2 Without MMT
Reforming Severity, RON	92.6	92.8	96.7	96.4	99.2
Isomerization Capacity, m^3/d	0	492	0	992	985

In 1985 (Case I), the existing unit capacities were capable of meeting the product slate and gasoline octane requirements. Thus, no capital was required in this case. The 0.44 g/L lead level is consistent with current levels in Ontario. The catalytic reformer severity was 92.6 RON.

For the 1990 approved lead level scenario in Ontario (Case II), two refinery base cases were run representing different methods of meeting the 0.29 g/L lead limit. With one approach, the reformer severity was allowed

to increase to the level required to meet the octane requirements posed by the lead restriction. In this case, the required reformer severity was 96.7 RON and modifications would likely be necessary. With the second approach, new isomerization capacity was made available, as needed, to meet octane requirements and the reformer severity was restricted to less than 93 RON. In this case, the isomerization capacity was selected by the LP optimization at 492 m^3/d. The isomerization unit represented in the LP totally isomerizes the feed stream (light straight run gasoline) to isomerate gasoline. Depending on the quality of the feed stream, the unit will increase the octane of the stream by 15-20 octane numbers (R+M/2). The capital costs for this case reflects the new isomerization unit. The case with the new isomerization unit involved more definitive changes for meeting octane requirements for the approved lead level scenario and was used as the base for comparison with oxygenate cases.

In the 1990 reduced lead level scenario in Ontario, reformer severity was allowed to find its optimal level and isomerization capacity was made available, as needed, to meet the increased octane requirements posed by the low (0.027 g/L) lead level restrictions. In the case with no MMT (Case 1), a reformer severity of 99.2 RON and isomerization capacity of 985 m^3/d was needed to meet octane needs. The capital costs in this base case reflect the cost of a new isomerization unit and modifications to the reformer to allow it to operate at high severity levels. In the case with MMT allowed (Case 5), a 992 m^3/d isomerization unit is still needed, but reformer severity can be reduced to 96.4 RON.

The base case results for other refineries and locations are summarized as follows:

BASE CASE OPERATIONS - COMPARISON

	Ontario - FCC		Ontario - Hydrocracking	
	Case II Approved Lead	Case 5 Reduced Lead	Case 9 Approved Lead	Case 10 Reduced Lead
Reforming Severity, RON	92.8	96.4	95.8	99.8
Isomerization Capacity, m^3/d	492	992	638	639

	Prairie		Quebec/Atlantic	
	Case 12A Approved Lead	Case 12B Reduced Lead	Case 13A Approved Lead	Case 13B Reduced Lead
Reforming Severity, RON	91.1	97.8	93.8	95.4
Isomerization Capacity, m^3/d	0	300	400	796

In the approved lead cases, reforming severity was restricted to current capabilities, and isomerization capacity was selected by the LP to meet octane requirements with 0.29 g/L lead. In the Prairies, no isomerization was needed, and reforming severity was well below current capabilities, estimated about 98 RON for the modern Edmonton refineries. The Ontario, hydrocracking refinery required almost 96 RON because of aromatics production.

In the reduced lead cases (with MMT), isomerization capacity and reforming severity were increased to meet octane requirements. This required further capital investment. In the Prairies, reforming severity was within the current capabilities, although some isomerization was required.

OXYGENATE OPERATIONS

Each of the oxygenate cases presented in Table 1 were simulated

using the refinery LP. The oxygenate was assumed to be a purchased input into the refinery and was forced into the specific gasoline grade(s) at the prescribed percentage. The detailed results of the oxygenate cases are given in tables in the Appendix. These tables show the comparison of the oxygenate case with the base case and the resulting material balance, economics and operational changes.

The significant refinery operational changes are summarized in Table 9. When oxygenates were added to gasoline, reforming severity was reduced, and isomerization capacity was reduced to varying degrees. At the approved lead levels, isomerization was eliminated from the Ontario/British Columbia - FCC refinery (Case II and 11A, respectively) to avoid capital investment. In the Ontario - hydrocracking refinery (Case 9) and the Quebec/Atlantic refinery (Case 13A), some isomerization was required, even with oxygenate addition, to meet octane requirements. In the Prairies, isomerization was not needed, even in the base case (Case 12A), as noted earlier.

In the reduced lead cases, isomerization was needed in most oxygenate cases. The major exception was in the Prairies, where oxygenates allowed new investment in isomerization to be avoided.

CRUDE AND BUTANE BACKOUT

The operations in Table 9 are summarized in terms of butane and crude backout ratios. These are the volumes of butane and crude oil reduction per volume of oxygenate used, compared with the base case (without the oxygenates). The approach of this study is to compare refinery operations with and without oxygenate using the same product slate. Therefore, when oxygenate is purchased for direct addition to gasoline, lower volumes of refinery components are required to produce the same volume of gasoline. The refiner must modify refinery operations to reduce butane and other gasoline components, resulting in reduced purchase of butane and/or crude oil.

An example may clarify the above relationships in the refinery. Assume 100 litres of an alcohol oxygenate is blended into the refinery

ULR gasoline. If the gasoline production from the refinery is to remain constant, as it does in this study, then 100 litres of other gasoline components must be backed out of the unleaded regular pool. Because of the high vapour pressure of the alcohol oxygenate, butane is normally the first component backed out of the pool when vapour pressure is limiting, since it also has a high RVP (60 psia). The amount of normal butane backout depends on its vapour pressure in relation to that of the oxygenate. In many cases, the butane backout ratio was about 0.4. Therefore, 40 litres of butanes would be backed in this example. The other 60 litres would come from the reduction of the other blend components. This would be accomplished through the decrease in crude input to the refinery and the resulting decrease in the production of other gasoline components. Since this reduction involves incremental crude, up to 75% of the crude could go into the production of gasoline depending on refinery flexibility. Thus, the backout of 60 litre of other components in the gasoline pool could result in a crude backout of 80 litres. In this example, the crude backout ratio is 0.8 and the total crude plus butane backout ratio is 1.2.

The reduction in butane and crude oil purchases (or backout) are significant in the economics of oxygenates, as these represent major cost savings to offset the purchase of the oxygenate. Since the price of crude oil is higher than the price of butane, crude oil backout benefits oxygenates the most. However, the combined crude plus butane backout has the greatest impact on oxygenate economics, as this represents the total reduction in feedstock purchases.

The butane and crude backout ratios vary among the oxygenates, and also among the various cases. The butane backout ratio varies among oxygenates because of varying RVP blending values. The highest RVP oxygenate, 5% methanol/3% TBA, reduces butane purchase by 0.34 to 0.62 litre per litre of oxygenate. The lowest RVP oxygenate, MTBE, has a butane credit, in most cases, (up to 0.17 litre per litre of MTBE); i.e., it allows increased additional butane purchase. Crude reduction tends to balance oxygenate purchase and butane reduction, so it is generally lower when butane reduction is high and vice versa. Crude backout is as high as 1.44 for MTBE since butane

backout is low. With high RVP, 5% methanol/3% TBA crude backout ranges from 0.30 to 1.08.

The total crude plus butane backout ratio varies from 0.90 to 1.42. The variation is more among the cases than among the oxygenates (within each case), as the maximum variation among alcohols within a case is 0.12. A summary of crude plus butane backout ratios is given below for the alcohols:

CRUDE AND BUTANE BACKOUT RATIO

Case No.	Description	Alcohols Only
I	1985, Ontario	1.23-1.29
II	Ontario - FCC, Approved Lead	1.06-1.20
1	Ontario - FCC, Reduced Lead, no MMT, Slate A	1.30-1.38
4	Ontario - FCC, Reduced Lead, no MMT, Slate B	1.35-1.42
5	Ontario - FCC, Reduced Lead, with MMT	1.09-1.14
6	Ontario - FCC, FEVI Specification	1.09-1.13
7	Ontario - FCC, Summer	1.20-1.31
8	Ontario - FCC, Winter	1.04-1.08
9	Ontario - Hydrocracker, Approved Lead	0.98-1.00
10	Ontario - Hydrocracker, Reduced Lead	1.27-1.33
12A	Prairie - Approved Lead	1.04-1.05
12B	Prairie - Reduced Lead	1.08-1.09
13A	Quebec - Approved Lead	0.90-0.92
13B	Quebec - Reduced Lead	1.06-1.07

Oxygenates should have the greatest economic value when the crude plus butane backout is high. Therefore, the changes in refinery conditions which change the crude plus butane backout will change the value of all the oxygenates as a group. For a given market scenario (refinery operation, lead levels, location, etc.), the value of oxygenates relative to each other are dependent on the differences in butane backout versus crude oil backout.

VOLATILITY

Most of the cases in this analysis were based on a gasoline specification in which the % off at 70°C is less than 46% on a year round basis. This is a proposed volatility specification, and did not limit the blending of oxygenates in gasoline. Instead, the gasoline RVP is the limiting specification, and when blending oxygenates, butane was backed out until the RVP limit was reached.

Several sensitivity cases were evaluated in which the % off at 70°C is less than 40% (the current ASTM specification). This lower volatility specification could limit, or at least penalize, the blending of the highly volatile oxygenates such as ethanol and methanol/ethanol. With these oxygenates, in many cases, butane in gasoline had to be further reduced to meet the % off specification, causing the RVP of gasoline to be below the maximum allowable. When the % off spec at 70°C was reduced from 46% to 40% off, the butane backout was increased considerably, and crude backout was not decreased to the same degree, so the oxygenates were penalized. A further sensitivity was carried out for methanol/ethanol blend by reducing its % off from 150% to 125%, with the current gasoline specification. If the blending volatility of this blend were as low as 125%, it would not be penalized as heavily for butane backout. These results are shown in Table 9, under Volatility Sensitivity (Cases II, 1 and 5).

CAPITAL COSTS

In the base cases, new isomerization facilities and/or catalytic reformer modifications were required. In the oxygenate cases, the above type of process changes were needed, although to a lesser degree, and some extra offsite facilities were needed for receiving, storage, handling and blending of oxygenates. Since these were new facilities, capital investment was required. Increased operating costs were assigned to new facilities.

The major capital and fixed operating cost components are given in Table 10. Based on the estimated capital cost, capital recovery changes

were estimated at 25% per year for depreciation, interest on debt, income tax, and return on equity.

The fixed operating costs for new facilities include operating labour, overhead, maintenance, insurance and local tax. Fixed costs apply only to the new isomerization units. Reformer changes should not affect fixed operating costs, and operating costs of new offsites facilities are negligible.

Table 10 shows capital costs for oxygenate offsites, isomerization units and catalytic reformer changes. For oxygenate systems, we have estimated $1.8 million, and have assumed that refiners could adapt existing gasoline storage and pumping systems to handle an oxygenated gasoline blend. The isomerization capital and operating costs in Table 10 are for units of varying sizes. The catalytic reformer capital costs are most difficult to assess because they involve changes to existing units. Costs of changes are dependent on the specific changes required. Since this study is for a typical refinery, specific changes are unknown. They could involve major changes to heaters, reactors, heat exchangers, compressors, pumps and piping. For this study, we have applied capital costs, at one of three levels: catalyst changes, a "moderate" revamp, and an "extensive" revamp. These are dependent on the estimated current severity limit of existing reformers, and the severity required. Generally, we have selected catalyst changes for an increase in severity of up to 2.5 RON, a moderate revamp for a severity increase from 2.6 to 4.0 RON, and a major revamp for a severity increase greater than 4.1 RON.

The specific capital fixed costs for each case are summarized in Table 11. These combine the cost components for all the new facilities required. The capital and operating cost savings due to the use of oxygenates are the difference between the costs of the base case and the costs of the oxygenate case. These costs and differentials are presented for each case in the tables in the Appendix.

OXYGENATE VALUES

A breakeven refinery value of the oxygenate has been calculated

for each of the oxygenate cases. The breakeven value is defined as the price the refiner can afford to pay for the oxygenate such that no economic penalty or gain results from its use as a blend component in the oxygenated gasoline pool. This refinery value excludes the downstream costs (if any) for supply and distribution systems, including marketing terminals and retail outlets. (These may include facility modification, system dryout, etc., see Section VII.) From the refinery breakeven value, a refiner's margin has been calculated based on an estimated supply cost of the oxygenate.

Each oxygenate case was compared to the base case to determine the refinery yield changes that resulted from the use of the oxygenate in the gasoline blending. The appropriate input and product prices were applied to yield differentials to give the cost and revenue changes at the refinery. The price of the oxygenate was placed at zero for this calculation. Additionally, the variable, fixed, and capital cost differentials were calculated for the oxygenate cases as compared to the base case. The total revenue change in dollars per day for the refinery was then calculated. Dividing the revenue change by the volume of oxygenate brought into the refinery gave the breakeven value of the oxygenate to the refiner.

The difference in the breakeven value and the estimated market price provides the margin the refiner could expect by using the oxygenate. Depending on the market price of the oxygenate, this margin can be positive or negative. The tables in the Appendix present the revenue change, breakeven value, estimated market price and refiner's margin for each of the oxygenate cases analyzed. The refiner's margin is given in dollars per day, cents per litre of oxygenate, and cents per litre of oxygenated gasoline. The results of the oxygenate economics for all cases are summarized in Table 12.

OXYGENATES

The widest selection of oxygenates were evaluated under Case I (1985 market) and Case II (1990 approved lead market), both in Ontario. The results of the breakeven analysis are summarized as follows:

REFINERY BREAKEVEN VALUE OF OXYGENATES, ONTARIO
(Cents per Litre of Oxygenate)

	Case I 1985 Market	Case II 1990 Approved Lead
10% Ethanol	27.7	26.6
Methanol/Ethanol (5%/3%)	27.0	24.2
Methanol/IPA (4.75%/4.75%)	28.8	26.0
(7%/3%)	-	25.5
Methanol/IBA (4.75%/4.75%)	27.9	24.9
(7%/3%)	-	24.1
Methanol/TBA (4.75%/4.75%)	26.5	23.9
(5%/3%)	-	22.6
(7%/3%)	-	24.2
11% MTBE	30.2	27.1
Toluene	-	29.4

Since the gasoline blending properties are similar, the refinery breakeven values of the oxygenates are similar. Among the oxygenates, MTBE has the highest value because of its low vapour pressure and low butane backout. Toluene has a high value for the same reasons. The values for the 1990 approved lead case are slightly lower, mainly due to reduced energy costs (in 1985 dollars).

The refinery margins for the same cases are summarized as follows:

REFINERY MARGIN, ONTARIO
(Cents per Litre of Oxygenate)

	Case I 1985 Market	Case II 1990 Approved Lead
10% Ethanol	(6.2)	(6.4)
Methanol/Ethanol (5%/3%)	3.1	2.3
Methanol/IPA (4.75%/4.75%)	(3.9)	(1.5)
(7%/3%)	-	2.9
Methanol/IBA (4.75%/4.75%)	(5.1)	(3.1)
(7%/3%)	-	1.2
Methanol/TBA (4.75%/4.75%)	(3.0)	0.2
(5%/3%)	-	1.1
(7%/3%)	-	3.9
11% MTBE	(9.8)	(0.5)
Toluene	-	(1.1)

The refinery margin is the difference between the breakeven value and the estimated supply cost. Because supply costs vary, therefore, the refinery margin also varies. In the 1985 market, only methanol/ethanol has a positive margin (about 3¢/L), and this assumes that ethanol can be made available at 34¢/L. In the 1990 approved lead case, the methanol/ethanol is still economic, as are the methanol/TBA blends. The 7% methanol/3% IPA blend is also economic, but it appears that a 5% methanol/3% IPA blend would not be economic. The economics of all these blends are affected adversely if gasoline volatility restrictions are more severe. This is discussed later.

In Ontario, MTBE is marginally uneconomic. This, of course, is dependent on how MTBE is supplied and at what cost. The cost here is based on a grass roots plant to produce MTBE from isobutane, so is dependent on isobutane cost. Some refiners may be able to install small-scale facilities to convert refinery isobutylene to MTBE, at lower cost.

A 1985 sensitivity case was analyzed, where unleaded regular gasoline yield was increased by 3% to offset the estimated decrease in energy content resulting from the blending of the oxygenate. Methanol/TBA at a 4.75%/4.75% ratio was used as the base. This sensitivity case shows an

increase in the breakeven value of the oxygenate of 1.4¢/L. The change in refiner's margin is less than 0.15¢/L of unleaded gasoline.

The oxygenates used in this study were forced into the gasoline pool according to the prescribed blends. The blend levels are allowable, but may not be optimum.

The oxygenate blends selected for further study include: ethanol, methanol/ethanol, methanol/TBA (both 4.75%/4.75% and 5%/3%), and MTBE.

OCTANE REQUIREMENTS

A number of cases were evaluated in Ontario which, in general, show the impact of octane requirements on oxygenate values. These are summarized as follows:

REFINERY MARGIN VERSUS OCTANE, ONTARIO
(Cents per Litre of Oxygenate)

	Case I	Case II	Case 1	Case 4
Gasoline				
Lead	0.44	0.29	0.027	0.027
MMT	yes	yes	no	no
% Unleaded	54	70	70	90
Pool Octane, (R+M)/2[1]	84.9	87.2	89.9	90.1
Oxygenates				
10% Ethanol	(6.2)	(6.4)	(0.9)	-
5% Methanol/3% Ethanol	3.1	2.3	8.6	10.6
5% Methanol/3% TBA	-	1.1	7.8	10.4
4.75% Methanol/4.75% TBA	(3.0)	0.2	5.8	6.9
11% MTBE	(9.8)	(0.5)	4.4	-

Note: (1) Base Case.

The average octane of the gasoline pool is shown, and the cases are arranged in order of increasing octane. As pool octane requirements increase, the breakeven value of the oxygenates increase, and hence the refinery margin. In the future markets, methanol/ethanol and methanol/TBA

should be economic. MTBE requires reduced lead levels to become economic in Ontario. 10% Ethanol will probably never be economic, if its cost exceeds 33¢/L.

The sensitivity of oxygenate value to blending octane was examined. The MTBE octane blending number can vary by ±6 numbers, (R+M)/2. For this range, under the approved lead scenario (Case II), the refinery margin can vary ±0.9¢/L. In other words, MTBE can be economic with a base stock that is susceptible to MTBE blending. The 7% methanol/3% TBA blend was also examined (with current volatility specifications). For the base octane, its refinery margin is 3.9¢/L. If its octane blending number varies by ±4 numbers, its refinery margin can vary ±1.1¢/L. This implies that other methanol/TBA blends, containing less methanol, could have marginal economics at approved lead levels, depending on the susceptibility of the base stock to oxygenate addition.

Other octane cases were evaluated in Ontario as well. Case 2 was similar to Case 1 (reduced lead), except that MMT was allowed in Case 2. The results for 4.75% methanol/4.75% TBA compared as follows:

Case	Oxygenate In	Gasoline Pool Octane (R+M)/2	Refinery Margin for 4.75% Methanol/4.75% TBA
Case 2, with MMT	ULR only	89.0	(0.3)
Case 3, no MMT	All grades	89.9	3.9
Case 1, no MMT	ULR only	89.9	5.8

The use of MMT in Case 2 reduces the gasoline pool octane requirements and greatly reduces the value of oxygenates in comparison with Case 1.

Case 3 is similar to Case 1, except that oxygenate was added to all grades of gasoline, or 100%. In Case 1, oxygenate was added only to ULR gasoline which is 70% of the gasoline pool. Therefore, almost 43% more oxygenate was added in Case 3. This reduces the requirements for production of gasoline components from the refinery, and in effect changes the gasoline/distillate ratio from crude oil. Although butane backout is

identical (0.34 litre per litre) in each case, the crude backout is reduced from 0.98 litre per litre in Case 1 to 0.90 litre per litre in Case 3, as refinery flexibility is more constrained. The addition of large volumes of oxygenate (Case 3) is less economic.

In Case 5, oxygenates were added to all grades as well. Lead was at reduced level, and MMT was allowed. The results are as follows:

	Refinery Margin, ¢/L		
	Case 5	Case 3	Case II
10% Ethanol	(7.9)	-	(6.4)
Methanol/Ethanol (5%/3%)	1.8	-	2.3
Methanol/TBA (5%/3%)	1.5	-	1.1
(4.75%/4.75%)	(0.5)	3.9	0.2
11% MTBE	(2.7)	-	(0.5)

With MMT, the values of oxygenates are less than without. For instance, for 4.75% methanol/4.75% TBA, the negative 0.5¢/L margin compares with 3.9¢/L in Case 3 (without MMT).

Case 5 results are compared with Case II (approved lead) results above. There should not be a direct relationship between the two because Case II is based on approved lead, and oxygenate in ULR gasoline only, whereas Case 5 is based on reduced lead and oxygenate in all grades. However, it is noteworthy that the refinery margins are lower in Case 5 for all oxygenates, except 5% methanol/3% TBA. If oxygenates were added only to ULR gasoline (Case 3), their economics would likely be better than Case II.

VOLATILITY

A number of cases were used to assess the impact of volatility requirements on oxygenate values. Most of these were in Ontario. Case 5, discussed earlier, was a basis for much of this work. Case 5 represents a year round average refinery operation, with proposed CGSB specifications for RVP and distillation (% off). Other cases include Summer (Case 7) and Winter (Case 8) operations, in which the product slate and specifications change. Results of these cases are summarized as follows:

REFINERY MARGIN VERSUS SEASON, ONTARIO(1)
(Cents per Litre of Oxygenate)

	Case 8 Winter	Case 5 Average	Case 7 Summer
Maximum RVP, psia	15.5	13.6	11.5
Maximum % off at 70°C	52	46	40
Oxygenate			
10% Ethanol	(8.9)	(7.9)	(6.8)
5% Methanol/3% Ethanol	(0.2)	1.8	2.9
5% Methanol/3% TBA	(0.5)	1.5	2.4
4.75% Methanol/4.75% TBA	(2.0)	(0.2)	1.1
11% MTBE	(3.7)	(2.0)	0.9

Note: (1) With reduced lead, MMT in unleaded, oxygenates in all grades.

In Ontario, oxygenate economics are below average in winter and above average in summer. This is due to a changing product slate over the seasons. This is evident from the gasoline/distillate ratios, as follows:

GASOLINE/DISTILLATE RATIOS, ONTARIO

	Case 8 Winter	Case 5 Average	Case 7 Summer
Base Case	1.23	1.29	1.44
8% Oxygenate	1.13	1.19	1.32
11% Oxygenate	1.07	1.15	1.28

The gasoline/distillate ratio is based on the product slates in Table 2. When oxygenates are added to gasoline, the gasoline components from the refinery are reduced. In winter, when oxygenates are added, the gasoline/distillate ratio is reduced from an already low level. To balance the refinery product slate, FCC conversion levels are reduced, resulting in lower yields and less economic operation. In summer, when oxygenates are

added, the gasoline/distillate ratio is similar to the gasoline/distillate ratio in the average base case. Refineries have the flexibility to adjust operations economically.

The volatility specifications in most cases are based on proposed CGSB specifications. Current ASTM volatility specifications are more stringent. The sensitivity of oxygenates to % off specifications was analyzed, and summarized as follows:

REFINERY MARGIN VERSUS VOLATILITY SPECIFICATION, ONTARIO
(Cents per Litre of Oxygenate)

	Case II		Case 5		Case 6	Case 1	
	Proposed Spec(1)	Current Spec(2)	Proposed Spec(1)	Current Spec(2)	FEVI Spec	Proposed Spec(1)	Current Spec(2)
Oxygenate							
10% Ethanol	(6.4)	(12.9)	(7.9)	(11.5)	(8.5)	(0.9)	(7.6)
5% Methanol/ 3% Ethanol	2.3	(1.9)	1.8	0.3	1.2	8.6	6.7
5% Methanol/3% TBA	1.1	0.7	1.5	1.4	-	7.8	7.3
4.75% Methanol/ 4.75% TBA	0.2	(2.1)	(0.5)	(1.3)	(0.2)	5.8	5.1
7% Methanol/ 3% TBA	3.9	1.1	-	-	-	-	-
7% Methanol/ 3% IPA	2.9	(1.7)	-	-	-	-	-
7% Methanol/ 3% IBA	1.2	(1.8)	-	-	-	-	-
11% MTBE	(0.5)	(0.9)	(2.7)	(2.5)	(2.0)	4.4	4.5

Notes: (1) Proposed CGSB Specification, Maximum 46% off at 70°C, and 71 % off at 100°C.
(2) Current ASTM Specification, Maximum 40% off at 70°C, and 65% off at 100°C.
(3) FEVI = RVP + 0.13 (% off at 70°C) $\leq$ 16.7 psia.

The current specification affects alcohols adversely, especially those with the highest volatility, such as 10% ethanol and 5% methanol/3% ethanol. With the current specification, many of the oxygenates must backout more butane to meet % off, causing the RVP to be below the maximum allowed.

The methanol/ethanol volatility is estimated at 150% off at 70°C. This property is difficult to estimate and should be measured for a specific base stock. If the methanol/ethanol % off at 70°C were 125%, volatility would not be a constraint, and the refinery margin would improve by 2.9¢/L.

An average year round refinery operation was evaluated using the FEVI (Case 6). The FEVI specification is defined above. This specification is more stringent than the RVP and % off specifications used separately. For instance, at the maximum FEVI of 16.7 psia, if the RVP is 13.6 psia, the maximum % off at 70°C is 24%, and if the % off at 70°C is 46%, the maximum RVP is 10.7 psia. When the FEVI specification is imposed on the base case, the resulting RVP's of the three gasoline grades range from 13.6 psia to 11.5 psia.

When oxygenates are added, the RVP's are reduced even further. With highly volatile oxygenates (ethanol and methanol/ethanol), RVP's are lowest, and butane backouts are highest so the economics are poorer than without the FEVI specification. However, with lower volatility oxygenates, especially MTBE, the RVP's are not reduced as much; the economics actually improve but are still not favourable.

TECHNOLOGY

Oxygenate economics were evaluated for different refining technologies in Ontario. The results are summarized as follows:

REFINERY MARGIN VERSUS REFINERY TECHNOLOGY
(Cents per Litre of Oxygenate)

	Approved Lead		Reduced Lead	
	Case II FCC	Case 9 Hydrocracking	Case II FCC	Case 10 Hydrocracking
5% Methanol/3% Ethanol	2.3	0.1	1.8	7.2
5% Methanol/3% TBA	1.1	(0.8)	1.5	6.3
4.75% Methanol/4.75% TBA	0.2	-	(0.5)	4.6

At the approved lead level, the oxygenate economics with hydrocracking are poorer than with FCC technology. In the FCC case, oxygenates allow a reduction of catalytic reformer severity of 1-2 RON, resulting in yield improvement. With hydrocracking, no reduction in reformer severity is realized, although isomerization capacity is reduced.

At the reduced lead level, oxygenate economics with hydrocracking are improved significantly over FCC technology. In this case, the reformer severity is reduced by about 5 RON with hydrocracking compared with the FCC case where the severity reduction is about 3 RON.

LOCATION

Oxygenate economics were evaluated for five regions of Canada, so prices and costs were determined for all five regions. Refinery operations were modeled in only three regions, as British Columbia refinery operations were considered to be similar to Ontario operations, and Atlantic refinery operations were considered to be similar to Quebec operations. Economics of several oxygenates were assessed for the approved lead scenario (similar to Case II in Ontario), and the reduced lead scenario (similar to Case 5 in Ontario). The economics of methanol/ethanol (5%/3%) were assessed for summer operations, as well as year round operations.

In British Columbia, the approved lead level cases were first analyzed, based on the Ontario refinery LP results, and adjusted, based on one British Columbia refinery LP simulation. For the approved lead level there could be more leaded gasoline (and lower octane requirements) in British Columbia than in Ontario. With methanol/ethanol, the British Columbia refinery margin is estimated at 3.7¢/L based on the British Columbia model, compared with 2.6¢/L based on Ontario refinery operations. Thus, the economics of other oxygenates should also be improved by approximately 1.1¢/L in British Columbia, with approved lead levels. The relative pricing of crude oil, butane, and refined products is similar to Ontario, so the refinery breakeven values are almost the same. However, the oxygenate costs are estimated to be lower in British Columbia, so alcohol economics are slightly more attractive in British Columbia, and MTBE economics are greatly improved, as shown below:

REFINERY MARGINS, ONTARIO AND BRITISH COLUMBIA
(Cents per Litre)

	Approved Lead		Reduced Lead	
	Case II Ontario	Case 11A British Columbia	Case 5 Ontario	Case 11B British Columbia
Methanol/Ethanol (5%/3%)	2.3	3.7	1.8	2.0
Methanol/TBA (5%/3%)	1.1	3.0	1.5	2.3
MTBE (11%)	(0.5)	2.8	(2.7)	(0.4)

In Quebec and the Atlantic, refinery breakeven values are considerably less than Ontario values with approved lead levels, but similar to Ontario values at reduced lead levels.

REFINERY BREAKEVEN VALUES, ONTARIO AND QUEBEC
(Cents per Litre)

	Approved Lead		Reduced Lead	
	Case II Ontario	Case 13A Quebec	Case 5 Ontario	Case 13B Quebec
Methanol/Ethanol (5%/3%)	24.2	19.9	23.7	23.6
Methanol/TBA (5%/3%)	22.6	19.0	23.0	22.9
MTBE (11%)	27.1	24.8	24.9	25.5

Atlantic values are slightly less than Quebec values.

The Quebec values are below Ontario in the approved lead cases because the addition of oxygenates in Quebec does not allow a reduction in reforming severity, whereas there is some reduction in severity in the Ontario - FCC case. In the reduced lead cases, the reduction in reformer severity is similar between Ontario and Quebec.

Most of the oxygenates (except ethanol) are estimated to have higher costs in Montreal than in Sarnia, and still higher costs in Halifax. Thus, oxygenate margins are lower in Eastern Canada than in Ontario.

REFINERY MARGIN, ONTARIO AND EASTERN CANADA
(Cents per Litre)

	Approved Lead			Reduced Lead		
	Ontario	Quebec	Atlantic	Ontario	Quebec	Atlantic
Methanol/Ethanol (5%/3%)	2.3	(2.1)	(2.9)	1.8	1.6	0.8
Methanol/TBA (5%/3%)	1.1	(3.0)	(4.8)	1.5	(0.9)	(0.9)
MTBE (11%)	(0.5)	(3.3)	(5.8)	(2.7)	(2.6)	(4.6)

Oxygenate economics are less favourable in Eastern Canada than Ontario, although methanol/ethanol could be economic if low cost ethanol is available. Also, if oxygenate is used only in ULR gasoline (as in Ontario - Case 3), or if octane requirements are increased (such as by removal of MMT), all oxygenates would be more economic.

Oxygenates were evaluated in the Prairies. As in Quebec, the refinery breakeven values in the Prairies are much less than in Ontario in the approved lead case. With reduced lead, the values of alcohols are less than in Ontario, but the MTBE value was higher.

REFINERY BREAKEVEN VALUE, ONTARIO AND PRAIRIES
(Cents per Litre)

	Approved Lead		Reduced Lead	
	Case II Ontario	Case 12A Prairies	Case 5 Ontario	Case 12B Prairies
Methanol/Ethanol (5%/3%)	24.2	19.5	23.7	22.1
Methanol/TBA (5%/3%)	22.6	18.3	23.0	20.9
MTBE (11%)	27.1	24.1	24.9	26.6

In the approved lead case, oxygenates have low value, as the refinery can readily meet octane requirements without new isomerization facilities, even in the base case. Prairie octane specifications are lower than other areas of the country and the new, modern refineries are estimated to have the highest octane capabilities because of high reforming severity (around 98 RON) and large alkylation capacity. In the reduced lead case,

isomerization is needed in the base case, but not when oxygenates are added. With alcohols, some saving is possible with a reduction in reforming severity (3 RON), similar to Ontario, but backout of butane is more costly in the Prairies because of its low cost. MTBE on the other hand backs out mainly crude, and its high concentration (11%) allows a larger reduction in reforming severity (6 RON), so the value of MTBE is higher in the Prairies than in Ontario.

The supply costs of alcohol blends and MTBE are estimated to be lowest in the Prairies. The resulting refinery margins are summarized as follows:

REFINERY MARGIN, ONTARIO AND PRAIRIES
(Cents per Litre)

	Approved Lead		Reduced Lead	
	Case II Ontario	Case 12A Prairies	Case 5 Ontario	Case 12B Prairies
Methanol/Ethanol (5%/3%)	2.3	(0.9)	1.8	1.7
Methanol/TBA (5%/3%)	1.1	0.5	1.5	3.1
MTBE (11%)	(0.5)	0.9	(2.7)	3.4

In the approved lead case, alcohol blends are less attractive than in Ontario. Methanol/TBA (5%/3%) and MTBE are marginally economic. In the reduced lead case, oxygenates are at least as economic as in Ontario. All are economic, especially methanol/TBA and MTBE, if TBA or MTBE are produced from low cost isobutane.

The economics of methanol/ethanol (5%/3%) were evaluated for summer operations in all regions. The difference between summer and annual average results are as follows:

SUMMER VALUE OVER AVERAGE VALUE, METHANOL/ETHANOL
(Cents per Litre)

Ontario/British Columbia	1.1
Quebec/Atlantic	0.7
Prairies	(1.3)

The Ontario results were discussed earlier. In Quebec, the oxygenate value due to oxygenate addition is also higher in summer. In the Prairies, the summer value is lower than the year round average. The reduction in reformer severity is only 2.0 RON in summer, compared with 3.5 RON year round. In the summer case, the methanol/ethanol blend is constrained by the % off, so that the RVP of the unleaded regular gasoline is only 11.1 psia. This causes extra butane backout which is less economic than crude backout. The penalty for a higher volatility oxygenate (methanol/ethanol) is not representative of other oxygenates, so the penalty for methanol/TBA or MTBE for summer operation in the Prairies should not be as great.

ECONOMIC SENSITIVITIES

The sensitivity of oxygenate economics has been discussed earlier for gasoline blending properties and specifications such as octane and volatility. This discussion of economic sensitivities covers sensitivity to prices and costs, assuming no major change in refinery operations.

OXYGENATE PRICE

The sensitivity of the refiner's margin to varying oxygenate prices has been analyzed. For the 1985 Ontario case (Case I), the oxygenate blend price was varied from 20 to 40¢/L. Figure 2 shows the refiner's margin in ¢/L of ULR gasoline over the range of oxygenate prices. The estimated market price of the oxygenates is also presented to show where the margin is in relation to the breakeven value (0¢/L margin).

In the 1990 approved lead level cases in Ontario (Case II), the oxygenate price was also varied 20¢/L. The resulting refiner margins are given in Figure 3. For the 1990 reduced lead level (Case 1), the same 20¢/L price range for the oxygenates was used and shown in in Figure 4.

METHANOL PRICE

The methanol price was varied from 12¢/L to 22¢/L to determine the effect on the breakeven price of the cosolvents blended with methanol. All of the 1985 cases that had a cosolvent blended with methanol were analyzed. For 1990, the approved lead cases in Ontario were used as a basis. Oxygenates include the three methanol/TBA cases as well as methanol/ethanol, methanol/IPA (7%/3%) and methanol/IBA (7%/3%). The sensitivity of MTBE production cost to methanol price is also shown. Finally, MTBE price sensitivity to methanol was examined. The results of the analysis are presented in Figure 5.

The refinery breakeven values of cosolvents decrease with an increasing price of methanol. The 4.75%/4.75% blends have parallel slopes. The 5% methanol/3% ethanol case is more sensitive to methanol price changes because of its higher concentration of methanol. The 1990 methanol/TBA cases also show the greater sensitivity of the cosolvent breakeven price to the higher concentrations of methanol.

The refinery breakeven value of MTBE is insensitive to changes in methanol price as shown in Figure 5. However, production cost is affected since methanol is used in the production of MTBE. Under the 1990 approved lead case, the attractiveness of MTBE to the refiner (positive or negative margin) appears to be quite sensitive to the methanol price. In the 1990 reduced lead case, the refiner's margin remains positive, but decreases as the methanol price increases.

BUTANE PRICE

Sensitivity to normal butane price was also examined. The breakeven value and production supply costs were calculated for the 11% MTBE, 5% methanol/3% ethanol, and 5% methanol/3% TBA cases for a normal butane price range from 12¢/L to 22¢/L (isobutane cost was consistent with normal butane cost). The results of the analysis are given in Figure 6.

The refinery values of alcohols vary directly with butane price. In the 5% methanol/3% TBA case, the breakeven value remained higher than the supply cost over the butane price range analyzed. The margin to the refiner therefore, remained positive with the normal butane price change. In the case of MTBE, the refinery breakeven value is almost insensitive to butane price, but production cost is very sensitive to the isobutane price, which relates to normal butane price. As shown in Figure 6, the production cost of MTBE intersects the breakeven value at a butane price of about 14.5¢/L. If the butane price is lower, MTBE is economic; if the butane price is higher, MTBE is not economic as in this case. For the 1990 reduced lead case, the breakeven value equals the production cost when the normal butane price is about 20¢/L.

CRUDE OIL PRICE

The sensitivity of the oxygenate breakeven value to crude price was analyzed for the 11% MTBE, 5% methanol/3% TBA, and 5% methanol/3% ethanol. Crude price was varied from $\$190/m^3$ to $\$240/m^3$. The resulting oxygenate breakeven values over the price range were calculated for the same crude balances, assuming that all other costs and prices remain unchanged. The oxygenate values are shown in Figure 7. MTBE economics are most sensitive to crude costs, since MTBE backs out more crude than other oxygenates. The estimated supply costs of the oxygenates are not shown because many of these would likely vary as well with crude price.

The senstivities of oxygenate values to crude price shown here are for crude cost variations with all other costs and prices held constant. If crude prices change, other costs and prices should also change in the long-term. Directionally, the refinery values of oxygenates should vary with the price of crude oil.

CAPITAL COST

The sensitivity of the oxygenate breakeven value to capital cost was analyzed for the 1990 4.75% methanol/4.75% TBA cases. The capital cost estimates that have been used in the 1990 base cases are for the typical Ontario refinery. Some refineries may already have the needed flexibility and capacities to meet either the proposed or reduced lead limits, and do not need any capital investments. On the other hand, some refineries may need much more capital investment to meet the lead limits than was estimated for the base cases. Therefore, breakeven values were calculated over a range of zero capital cost to about 100% greater than the estimated differential between the base case and the oxygenate case. For the approved lead level case, the range used was zero to $25 million, and for the reduced lead case it was zero to $50 million. The breakeven value as a function of the change in capital cost is given Figure 8. In the reduced lead scenario, the oxygenates should still be economic, even if new capital investments are not needed.

VII
INDUSTRY

REFINING

This analysis is based on typical refinery operations in all regions of Canada. A summary of Hycarb's forecast for refining operations across Canada is given in Table 13. Total gasoline production in Canada in 1990 is estimated at 82,200 m^3/d. Total ULR gasoline production across Canada is estimated at 44,600 m^3/d in 1990 if the lead level of leaded gasoline is 0.29 g/L (the approved 1987 level). If lead is reduced to 0.027 g/L, it is expected that leaded gasoline price would increase relative to unleaded gasoline; misfuelling would be reduced, and production of ULR gasoline would increase to 57,600 m^3/d.

The typical refineries in this study are defined by their crude slate and quality, product slate and specifications, and process capabilities. The refining models are considered to be representative of the industry. Since no refineries are identical, the refining models do not represent specific refinery operations, but are reasonable bases for the economic evaluation of octane enhancers.

The refined product mix varies among refiners. Some have a greater market for leaded gasoline relative to unleaded gasoline. They could be affected most by lead phasedown. Some refineries produce more gasoline relative to middle distillate products than others. These refiners employ more upgrading technology to meet gasoline yield and quality. These refineries will require the greatest octane barrel improvements per barrel of crude with lead phasedown, and so could be affected by oxygenates.

In Ontario, most of the refineries have some specialty products such as asphalt, lube oils, naphtha specialties, petrochemical feedstocks, and aromatics (benzene, toluene, and xylenes). Refineries producing naphtha specialties and petrochemical naphtha have an outlet for some low octane material. Refineries which produce aromatics for petrochemicals are removing high octane components from the gasoline pool. As octane requirements

increase, aromatics removal may be more difficult. Also, availability of aromatics such as toluene for other refiners may be reduced.

Many refineries in Eastern Canada employ hydrocracking in addition to catalytic cracking. Hydrocracked naphtha increases reformer throughput requirements for gasoline production. Together, hydrocracking and increased catalytic reforming increase the refinery butane production, and reduce the need for purchased imports. Many of the hydrocracking refineries also produce aromatics. The components for gasoline blending from this process scheme are different than from catalytic cracking. The effect of oxygenates in the hydrocracking refinery are different from the catalytic cracking refinery as shown earlier.

The refining industry has developed over many years. Some refineries and refinery units are less than 10 years old and employ modern technology. Within older refineries, some units have been modernized or replaced. Of particular interest in a gasoline study is the catalytic reformer technology. Some older units use high pressure, semi-regenerative technology, and the average severity is probably less than 93 RON. New low pressure semi-regenerative units, and continuous regenerative units can achieve severities of more than 100 RON for extended periods. None of the Ontario refineries have isomerization units for increasing the octane of light straight run naphtha. We understand that a few Ontario refineries can produce gasoline which is mostly unleaded with present facilities. These operators would be less interested in purchasing octane enhancers than other operators who may need capital investment to meet future octane requirements.

Refineries in Quebec and the Atlantic Provinces use a mix of foreign and Canadian crude oils. Like Ontario refineries, some have specialty operations and some have been modernized more recently than others. We understand that some of the refineries in these regions have less octane production capability than Ontario, so operators should have some interest in octane enhancers as an alternative to new investment.

In the Prairie Provinces, most of the refining capacity is recent and employs modern, efficient technology. Some refiners have extensive

alkylation capacity to use inexpensive field butanes for supplemental gasoline production. The octane specifications are lower in the Prairie Provinces because of altitude. Also, the Prairie gasoline market has the highest proportion of leaded gasoline. Because of high octane capability and lower octane requirements, most Prairie refineries do not have serious octane limitations. There may be some exceptions, as a few small refineries do not have as modern technology. Recent refinery construction has added considerable surplus capacity in the Prairie Provinces. Some rationalization of capacity may be needed in Western Canada. Refiners who have octane problems may be reluctant to make capital investments at this time so may be interested in octane enhancers. In addition, methanol supply costs are lowest in Western Canada because of the local production.

In British Columbia, most of the refineries are old, and have been modernized to varying degrees. We understand that some are likely to be octane short after lead phasedown. There is considerable excess refining capacity in the Prairies. Since the Prairie refineries are larger, and more modern and efficient, they can move product further into British Columbia. Changes to the Trans Mountain pipeline are underway which will facilitate more product movement. Also, more products may be imported into British Columbia. Since several of the Vancouver refineries have sister refineries at Edmonton, shutdown of some British Columbia refineries is possible. Consequently, refineries there are hesitant to make capital investments. Some refiners with octane problems could welcome octane enhancers as long as long-term commitments were not required.

MARKETING/DISTRIBUTION

At each refinery three grades of gasoline are normally blended from several gasoline components produced within the refinery. There are storage and handling systems for all the components and finished grades. Depending on the refinery location, finished product is distributed from the refinery by truck, rail, ship or pipeline. Truck movements may be direct to consumer outlets. Product is also moved by truck and other means

to intermediate storage terminals for further distribution by truck to consumer outlets.

Product is moved by pipeline from refineries in Sarnia, Toronto, and Montreal to the Ontario market. Pipelines carry product from Edmonton to terminals at Regina, Winnipeg, and Calgary, and in the future to Kamloops and probably to Vancouver. Most product pipelines are shared by more than one shipper. Products are batched for each shipper and retained in its custody. There are no fungible product pipelines in Canada as there are in the U.S. With a fungible product operation all shippers' products are comingled and must meet common specifications.

In Canada, refiners have their own marketing/distribution systems. There are also independent gasoline wholesalers and retailers who purchase gasoline from domestic refiners, or foreign suppliers. Refiners also supply products to the refiners in one region, in exchange for products in another region, in order to minimize transportation costs.

Octane enhancers might be added to gasoline base stock at intermediate terminals, or even consumer outlets by pump blending. Traditionally, refiners have blended all components to finished grades at the refinery.

MTBE is completely miscible in gasoline, and so does not present any handling problems. In the U.S. it is allowed in fungible product pipelines without identification. There is some risk of further addition of oxygenate downstream, causing oxygen limits to be exceeded.

The use of methanol as an octane enhancer requires the use of cosolvents to prevent phase separation in the presence of water, as previously discussed. To avoid alcohol losses, and water disposal problems, the entire gasoline distribution system from refinery to consumer tank, must be kept free of water. This may require increased monitoring and effort. In addition, high concentration of methanol may introduce problems of incompatibility with certain materials such as piping gaskets, and tank liners. Some retailers are concerned about customer acceptance, and some automobile manufacturers will not honour warranties for automobiles which have used fuels containing methanol. In the U.S. market, many refiner/

marketers are using methanol blends, while others vigorously oppose their use. Some use ethanol, but not methanol.

In Canada, there are two commercial marketers of oxygenated gasoline. Mohawk, an independent marketer, markets alcohol fuels, both gasohol and methanol/ethanol gasoline blends in Western Canada. V-plus, owned by Alberta Gas Chemicals (a methanol producer) and managed by Sunoco, markets methanol/IBA gasoline blends in Ontario. Other refiners have evaluated oxygenates, but to our knowledge have made no commitments for or against their use. If methanol blends are to be used in the gasoline market, it seems likely that one or a few refiners and/or marketers will introduce the product in selected areas.

For commercial marketing of oxygenate gasoline, refiners could choose to market alcohol blends only in the refinery area by truck, and not to distribute alcohol blends via pipeline. Also, they might have exchange agreements with other refiners who may not be willing to use alcohol blends. For these reasons, the refiner would have to blend, store and handle two grades of ULR gasoline, at least during the introductory years. This would represent another gasoline grade in the system. If alcohols were added to other gasoline grades as well, additional grades would be added rather than replaced. In the long run, as the proportion of leaded gasoline declines, particularly if lead limits are further reduced, the refiners may choose not to produce and market leaded gasoline, so additional facilities would become available for oxygenated fuel.

The production and handling of extra grades adds complexity to the system. Additional facilities are needed at the refinery, and may be needed throughout the system depending on distribution strategy. There would likely be some additional operating costs and perhaps capital costs. Capital costs may be minimal as there should be redundant equipment in the distribution/storage systems because of throughput reductions in recent years. There may be some initial capital and start-up costs to distributing oxygenated fuels. This study was not intended to determine distribution costs for alcohol blends, but any incremental costs are detrimental to alcohol economics. Once the system is dried out and operating, the extra costs should be

minimal. The concentration of cosolvents can probably be reduced once the system is dry, thus reducing oxygenate costs.

BUTANE

The use of oxygenates in gasoline could increase or decrease demand for butane. Some of the oxygenates have high vapour pressure, and will back butane out of gasoline. The 5% methanol/3% ethanol blend could back out as much as 0.75 litre butane per litre of oxygenate. If all gasoline in Canada was oxygenated with 5% methanol/3% ethanol, refinery demand for butane could fall by about 5,000 m^3/d.

TBA blends with methanol could reduce normal butane demand by refineries, but TBA production would create a demand for isobutane. The isobutane feedstock requirement is 1.23 litres per litre of TBA. A blend of 5% methanol/3% TBA would use about 0.46 litres of isobutane per litre of alcohol. Methanol/TBA blends backout 0.4-0.5 litres of butane per litre of alcohol, so changes in the butane balance are negligible with methanol/TBA blends, if isobutane is converted from normal butane.

MTBE has low vapour pressure, and can allow slightly more butane in the gasoline blend. MTBE production from isobutane feedstock requires about 0.96 litre per litre of MTBE. If all gasoline in Canada contained 11% MTBE, butane demand would increase by more than 8,000 m^3/d.

Production of isobutane at Sarnia might utilize excess butane isomerization capacity at the Dome plant. Isobutane is also available at Edmonton.

OXYGENATES

For one typical Ontario-FCC refinery in this study, oxygenate use was as much as 11% of gasoline, or 800 m^3/d. Methanol was up to 7%, or 510 m^3/d, and other cosolvents were up to 4.75%, or 350 m^3/d. Potential demand in Canada for oxygenates in gasoline is summarized below:

POTENTIAL OXYGENATE DEMAND
(Cubic Metres per Day)

	Typical Refinery	Ontario	Canada
Total Gasoline	7,300	28,900	82,200
Maximum Oxygenate (11%)	800	3,180	9,040
Maximum Methanol (7%)	510	2,020	5,750
Maximum Cosolvent (4.75%)	350	1,370	3,900

The oxygenate markets in Canada were discussed earlier. The current surplus of methanol in Canada is approximately 5,500 m^3/d. A surplus will remain unless all gasoline in Canada contains 7% methanol. There are insufficient quantities of other oxygenates available in Canada, even for the typical refinery, so future requirements will have to be imported or produced from new plants.

For the Ontario market, we have assumed new plants could be constructed at Sarnia for 605 m^3/d of IPA or TBA, or 1,020 m^3/d of MTBE. This represents the potential demand (for about half the Ontario ULR gasoline). IPA economics for a new plant do not look attractive; therefore, new production is not expected, but the present surplus of 125 m^3/d might be used for fuels as an incremental market. The present surplus of 84 m^3/d of IBA may be used for gasoline blending, but large expansion is not expected. Ethanol could be produced, but its economics seem doubtful, if imports are allowed to enter Canada at $1.00 (U.S.)/U.S. gal. Ethanol can be produced by a variety of fermentation processes. New technology is being developed to use natural gas and methanol (also derives from natural gas).

If a cosolvent or MTBE plant were constructed at Sarnia, it could serve the Ontario and Quebec markets. In addition, it could serve part of the U.S. Midwest market, where proposed lead restrictions may increase demand for octane enhancers.

The smaller Atlantic market might be supplied with methanol from Alberta and cosolvent and/or MTBE from Sarnia. Another possibility is for a

Canadian methanol producer to exchange product on the Pacific for methanol delivered on the Atlantic Ocean. Ethanol imports may be the most attractive cosolvent here. The combined Quebec and Atlantic potential market for oxygenate is less than the Ontario market.

The British Columbia market can be readily supplied with methanol. Cosolvent supply is more difficult. Potential demand for oxygenates for the entire British Columbia market is slightly more than the single Ontario refinery of this study, i.e. up to 680 m^3/d methanol or 460 m^3/d of cosolvent. The existing British Columbia refining industry is threatened with oversupply from the Prairies, and increased imports after deregulation. Refiners there would not likely be willing to invest in or enter into long-term contracts for cosolvent supplies.

There is a possibility of constructing a cosolvent or MTBE facility in Alberta or British Columbia for the export market. In this study, production of MTBE or TBA was assumed in Alberta, using low cost isobutane and serving western markets. Without these types of facility, import of ethanol is the most likely source of cosolvent. Although oxygenate values are low in Prairie refineries, their production costs are also low, so oxygenates can be economic. The total western Canadian market (Prairies and British Columbia) is potentially larger than the Ontario market.

Other oxygenates which were not part of this study, may be attractive in the future. For instance, if methanol technology can be successfully modified for mixed alcohols, the mixed alcohols may be suitable for gasoline blending, depending on their blending properties, and supply costs.

The oxygenate values determined in this study are based on a number of specific refining situations, and prescribed blends of oxygenates. Oxygenates might have higher value if added to gasoline at optimum levels. In some cases, high levels of oxygenate addition caused excessive backout of butane from the refinery. Results also showed that an oxygenate added to all gasoline grades had lower value than when added to only one grade.

The oxygenate values are based on meeting conventional gasoline specifications. Some argue that driveability with oxygenated gasoline

improves with higher volatility. If oxygenated gasoline was allowed a higher volatility than conventional gasoline, the value of oxygenates would likely increase.

TABLES

TABLE 1

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

CASES ANALYZED

ONTARIO

Study Parameters	Gasoline Octane							Gasoline Volatility			Refining Technology	
Case Number	I	II	1	2	3	4	5	6	7	8	9	10
Basis												
Refinery Type	Catalytic Cracking (FCC)										Hydrocracker/FCC	
Product Slate	1985	"A"	"A"	"A"	"A"	"B"	"B"	"B"	Summer	Winter	"A"	"B"
Maximum Lead (g Pb/L)	0.77(1)	0.29	0.027	0.027	0.027	0.027	0.027	0.027(2)	0.027	0.027	0.29	0.027
MMT (0.018 g Mn/L)	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Gasoline Grade(s) With Oxygenate	ULR	ULR(3)(4)	ULR	ULR	All	ULR	All	All	All	All	ULR	All
Octane Enhancers												
MTBE (11%)	x	x(3)(4)	x(4)				x(4)	x	x	x		
Ethanol (10%)	x	x(4)	x(4)				x(4)	x	x	x		
Methanol/Ethanol (5%/3%)	x	x(4)(5)	x(4)			x	x(4)	x	x	x	x	x
Methanol/TBA (4.75%/4.75%)	x(1)	x(4)	x(4)	x	x	x	x(4)	x	x	x		x
(5%/3%)		x(4)	x(4)			x	x(4)	x	x	x	x	x
(7%/3%)		x(3)(4)										
Methanol/IPA (4.75%/4.75%)	x	x										
(7%/3%)		x(4)										
Methanol/TBA (4.75%/4.75%)	x	x										
(7%/3%)		x(4)										
Toluene (as required)		x	x									

OTHER LOCATIONS

Location	British Columbia(6)			Prairies			Quebec			Atlantic(7)		
Case Number	11A	11B	11C	12A	12B	12C	13A	13B	13C	14A	14B	14C
Basis												
Refinery Type	FCC			FCC/ Hydrocracking			FCC/ Hydrocracking			FCC/ Hydrocracking		
Product Slate	"A"	"B"	Summer	"A"	"B"	Summer	"A"	"B"	Summer	"A"	"B"	Summer
Maximum Lead (g Pb/L)	0.29	0.027	0.027	0.29	0.027	0.027	0.29	0.027	0.027	0.29	0.027	0.027
MMT (0.018 g Mn/L)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gasoline Grade(s) With Oxygenate	ULR	All	All	ULR	All	All	ULR	All	All	ULR	All	All
Octane Enhancers												
MTBE (11%)	x	x		x	x		x	x		x	x	
Methanol/Ethanol (5%/3%)	x(6)	x	x	x	x	x	x	x	x	x	x	x
Methanol/TBA (5%/3%)	x	x		x	x		x	x		x	x	

Notes: (1) Including sensitivity for higher yield for heat content for Methanol/TBA.
(2) Front end volatility index specification for all cases.
(3) Including sensitivities for octane blending value.
(4) Including sensitivities for low volatility specification.
(5) Including sensitivity for low volatility of methanol/ethanol.
(6) British Columbia economics based on Ontario FCC LP results, except for methanol/ethanol with approved lead (Case 11A).
(7) Atlantic economics based on Quebec LP results.

TABLE 2

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

TYPICAL REFINERY BALANCES AND CAPACITIES(1)
(Cubic Metres per Day)

Case Number	I	II,1-3,11A	4-6, 11B	7	8	9/10	13/14		12	
	Ontario and British Columbia						Quebec and Atlantic		Prairie	
	Catalytic Cracking									
	1985(4)	Product Slate 'A'	Product Slate 'B'	Summer(4)	Winter(4)	Hydro-Cracking(4)	Average	Summer	Average	Summer
Crude										
Import	-	-	-	-	-	-	6,100	6,100	-	-
Synthetic	2,300	2,800	2,800	2,800	2,800	2,000	-	-	6,000	6,000
Conventional Light	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Products										
Gasoline(3)										
Leaded	3,640	2,190(3)(4)	730	770	720	460(3)	490(3)	510	1,090(3)	1,120
Unleaded Regular	3,630	4,530(3)(4)	5,110	5,350	5,010	3,220(3)	3,410(3)	3,590	5,110(3)	5,250
Unleaded Premium	630	580	1,460	1,530	1,430	920(3)	980(3)	1,020	1,090(3)	1,120
Subtotal - Gasoline	7,900	7,300	7,300	7,650	7,160	4,600	4,880	5,120	7,290	7,490
Jet B	150	270	150	150	150	100	160	160	520	550
Jet A	690	690	810	880	780	400	590	710	480	510
Kerosene	130	90	90	90	90	70	70	70	210	210
Diesel										
Winter	1,580	1,750	1,750	-	2,360	1,320	1,220	-	3,280	-
Summer	1,050	1,170	1,170	3,200	-	880	810	2,280	1,770	5,050
Subtotal - Diesel	2,630	2,920	2,920	3,200	2,360	2,200	2,030	2,280	5,050	5,050
LFO	2,100	1,530	1,700	1,000	2,430	830	1,730	1,120	240	240
Aromatics	-	-	-	-	-	400(5)	-	-	-	-
Total	13,600	12,800	12,970	12,970	12,970	8,600	9,460	9,460	13,790	14,010
Other (HFO, LPG, Still Gas)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Process Units/Capacities										
Crude	16,000	16,000	16,000	16,000	16,000	11,000	14,000	14,000	20,000	20,000
Vacuum	5,600	5,600	5,600	5,600	5,600	3,500	6,500	6,500	4,500	4,500
Catalytic Cracker	4,800	4,800	4,800	4,800	4,800	2,500	4,200	4,200	5,000	5,000
Alkylation	1,000	1,000	1,000	1,000	1,000	600	-	-	1,250	1,250
Polymerization	-	-	-	-	-	-	460	460	-	-
Catalytic Reformer	3,500	3,500	3,500	3,500	3,500	4,400	3,100	3,100	4,000	4,000
Visbreaker	-	-	-	-	-	700	-	-	-	-
Hydrocracker	-	-	-	-	-	2,000	1,000	1,000	2,600	2,600

Notes: (1) 1990 Product Slates, unless noted otherwise.
(2) To balance refinery operations.
(3) Leaded gasoline contains ≤0.027 g Pb/L, except: Ontario 1985 (<0.77 g/L),
Ontario - Product Slate "A" (<0.29 g/L), and
Others - Product Slate "A" (<0.29 g/L) below:

Gasoline				
Leaded	3,290(6)	1,380	1,460	3,800
Unleaded Regular	3,430(6)	2,850	2,830	3,200
Unleaded Premium	580	370	590	290
Total	7,300	4,600	4,880	7,290

(4) Ontario only.
(5) Maximum production. Allowed to make less if needed for octane requirements.
(6) British Columbia only.

TABLE 3

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

GASOLINE SPECIFICATIONS

Octane Specifications	Leaded[1] Regular	Unleaded[2] Regular	Premium[2] Unleaded
Average Octane, (R+M)/2, minimum			
Prairies	88.3	88.3	90.8
Other Locations	89.8	89.0	91.8

Volatility Specifications	Current Min.	Current Max.	Proposed[3] Min.	Proposed[3] Max.
RVP, psia				
Summer	-	11.0[4]	-	11.5
Average	-	13.0[4]	-	13.6
Winter	9.0[4]	15.0[4]	10.0	15.5
Boiling Point at 50% off, °C				
Summer	77[5]	118[4]	80	120
Average	77[5]	116	73	115
Winter	77[5]	113[4]	65	110
% Off at 70°C[6]				
Summer	20	40	15	40
Average	20	40	20	46
Winter	20	40	25	52
% Off at 100°C[6]				
Summer	35	65	35	65
Average	35	65	40	71
Winter	35	65	45	77

Notes:
(1) Lead content $\leq$ 0.77 g/L in 1985, $\leq$ 0.29 g/L in 1987.
(2) Manganese content $\leq$ 0.018 g/L.
(3) Proposed CGSB specification for oxygenated gasoline.
(4) Current CGSB specifications, CAN2 - 3.1 and CAN2 - 3.5.
(5) Based on current ASTM specification D439.
(6) As used in refinery LP model.

TABLE 4

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

CRUDE AND REFINED PRODUCT PRICES
(Dollars per Cubic Metre, 1985 Dollars)

	Vancouver 1990	Edmonton 1990	Sarnia 1985	Sarnia 1990	Montreal 1990	Halifax 1990
Conventional Light Crude(1)	212	207	250	213	215	208
Normal Butane	140	122	183	154	159	155
Isobutane	151	132	188	166	172	168
LPG (Propane)	117	100	154	129	146	128
HFO, 3% S	156	142	195	156	152	147
ULR Gasoline	265	260	320	269	271	267
Natural Gas(2)	123	91	177	143	143	147

Notes: (1) 38°API, 0.6 % S.
(2) Fuel Oil Equivalent.

TABLE 5

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

GASOLINE BLENDING PROPERTIES OF OXYGENATES AND OTHER COMPONENTS

Oxygenates	Octane									Volatility		
	Unleaded Regular			Unleaded Premium			Leaded Regular			RVP,	% Off	
	RON	MON	(R+M)/2	RON	MON	(R+M)/2	RON	MON	(R+M)/2	psia	at 70°C	at 100°C
Ethanol (10%)	134.0	102.0	118.0	135.5	103.5	119.5	135.3	103.2	119.3	20	148	105
Methanol/Ethanol (5%/3%)	125.0	99.0	112.0	126.5	100.5	113.5	126.3	100.2	113.3	37	150	85
Methanol/IPA (4.75%/4.75%)	125.5	98.5	112.0							26	130	95
(7%/3%)	127.5	99.5	113.5							28	135	90
Methanol/IBA (4.75%/4.75%)	122.0	95.0	108.5							27	120	105
(7%/3%)	125.5	96.5	111.0							33	125	100
Methanol/TBA (4.75%/4.75%)	119.0	97.0	108.0	122.0	100.0	111.0	122.9	101.3	112.1	33	120	105
(5%/3%)	121.5	97.5	109.5	124.5	100.5	112.5	125.1	101.2	113.2	42	125	100
(7%/3%)	123.0	98.0	110.5							35	125	100
MTBE (11%)	119.0	97.0	108.0	121.5	99.5	110.5	122.1	99.9	111.0	9	60	110
Toluene	115.0	97.0	106.0							1	0	0
Normal Butane	94.5	89.5	92.0							60	115	100

Note: (1) Lead content = 0.027 g/L.

TABLE 6

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ESTIMATED CHEMICAL PRICES
(Cents per Litre, 1985 Currency)

	Vancouver	Edmonton	Sarnia		Montreal	Halifax
	1990	1990	1985	1990	1990	1990
Methanol	13.7	11.7	18.0	15.2	15.7	17.0
Ethanol	33.0	35.0	33.9	33.0	32.5	31.2
IPA	-	-	47.4	39.7	-	-
IBA	-	-	48.1	40.8	-	-
TBA	30.0	28.0	41.0	32.1	32.6	33.9
MTBE	25.2	23.2	40.0	27.6	28.1	29.4
Toluene	-	-	35.9	30.5	-	-
5% Methanol/3% Ethanol	20.9	20.4	23.9	21.9	22.0	22.3
4.75% Methanol/4.75% IPA	-	-	32.7	27.5	-	-
7% Methanol/3% IPA	-	-	26.8	22.6	-	-
4.75% Methanol/4.75% IBA	-	-	33.0	28.0	-	-
7% Methanol/3% IBA	-	-	27.0	22.9	-	-
4.75 Methanol/4.75% TBA	21.9	19.9	29.5	23.7	24.2	25.5
5% Methanol/3% TBA	19.8	17.8	26.6	21.5	22.0	23.3
7% Methanol/3% TBA	-	-	24.9	20.3	-	-

TABLE 7

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

OXYGENATE PRODUCTION COSTS, 1990
(1985 Currency)

		MTBE		TBA		IPA
		Sarnia	Edmonton	Sarnia	Edmonton	Sarnia
Capacity: kta		275	275	175	175	175
	m^3/d	1,020	1,020	605	605	606
Capital Cost: $ Million		89.9	94.4	100.5	105.5	77.5
Feedstock:	Name	isobutane	isobutane	isobutane	isobutane	propylene
	Quantity	0.96 L/L	0.96 L/L	1.23 L/L	1.23 L/L	0.57 kg/L
	Cost	16.6¢/L	13.2¢/L	16.6¢/L	13.2¢/L	440$/t
	Name	methanol	methanol			
	Quantity	0.35 L/L	0.35 L/L			
	Cost	15.2¢/L	11.7¢/L			
Production Cost: ¢/L						
	Feedstock	21.3	16.8	20.5	16.2	25.1
	Operating	1.2	1.0	2.2	1.9	7.4
	Capital Recovery	5.1	5.4	9.4	9.9	7.2
	Total	27.6	23.2	32.1	28.0	39.7

TABLE 8

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

REFINERY BASE CASES

	Ontario - FCC					Ontario Hydrocracking		Prairies		Quebec/Atlantic	
		Approved Lead		Reduced Lead							
	1985	With Isomerization	Without Isomerization	With MMT	No MMT	Approved Lead	Reduced Lead	Approved Lead	Reduced Lead	Approved Lead	Reduced Lead
Case	I	II	II	5	1	9	10	12A	12B	13A	13B
Balance, m^3/d(1)											
Inputs											
Crude	14,120	13,273	13,404	13,576	13,492	8,826	8,843	14,000	14,228	11,598	11,658
Normal Butane	689	590	552	525	504	229	196	525	432	46	1
Isobutane	348	332	328	323	305	30	0	60	41	0	0
Outputs											
LPG	270	247	273	271	293	194	224	242	297	211	221
HFO	1,225	1,091	1,104	1,222	1,213	397	394	937	911	2,023	2,030
Fuel Gas and Loss	63	57	107	80	95	65	65	(298)	(258)	(105)	(114)
Aromatics	-	-	-	-	-	306	294	-	-	-	-
Economics											
Variable Operating Costs											
Purchased Fuel	279	276	300	308	327	450	476	741	801	292	305
Utilities, Catalyst, Chemical & TEL, M$/d	62.4	56.6	55.2	56.5	56.8	45.2	43.7	73.1	68.8	49.1	48.2
Fixed & Capital Costs, M$/d	0	12.8	10.0	28.7	39.2	14.8	24.6	0	11.1	11.4	18.5
Operational Changes											
Reformer Severity, RON	92.6	92.8	96.7	96.4	99.2	95.8	99.8	91.1	97.8	93.8	95.4
TEL Level, g Pb/L	0.44	0.29	0.29	0.027	0.027	0.29	0.027	0.29	0.027	0.29	0.027
MMT Level, g Mn/L	0.018	0.018	0.018	0.018	0.00	0.018	0.018	0.018	0.018	0.018	0.018
Unit Utilization, m^3/d											
Reformer	2,439	2,480	2,518	2,482	2,606	2,421	2,529	3,200	3,504	2,237	2,271
Alkylation	1,000	962	971	983	977	432	406	646	664	-	-
FCC	4,183	3,971	4,009	4,053	4,034	1,997	1,875	2,323	2,390	2,588	2,605
Hydrocracking	-	-	-	-	-	913	1,070	2,562	2,561	1,000	1,000
Polymerization	-	-	-	-	-	-	-	-	-	268	269
Isomerization	0	492	0	992	985	638	639	0	300	400	796

Note: (1) See Table 2 for full product slate.

TABLE 9

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

REFINERY OPERATIONS SUMMARY

Case Number	Case Description/Oxygenates	Refinery Backout Ratios(1) Butane	Crude	Crude + Butane	Reformer Severity RON	Isomerization Capacity m³/d	RVP, psia Oxygenate Blend	Leaded Regular	Unleaded Regular	Unleaded Premium
	ONTARIO									
I	1985 Market, ULR Only									
	Base Case	-	-	-	92.6	0	-	13.6	13.6	13.6
	Methanol/TBA (4.75%/4.75%)	0.39	0.84	1.23	90.5	0	33	-	13.6	-
	Methanol/IPA (4.75%/4.75%)	0.23	1.06	1.29	90.6	0	26	-	13.6	-
	Methanol/IBA (4.75%/4.75%)	0.26	1.00	1.26	90.6	0	27	-	13.6	-
	Methanol/Ethanol (5%/3%)	0.42	0.84	1.26	90.6	0	37	-	13.6	-
	Ethanol (10%)	0.28	0.99	1.27	91.8	0	20	-	12.7	-
	MTBE (11%)	(0.08)	1.35	1.27	90.6	0	9	-	13.6	-
	Sensitivity Case (Gasoline Yield)									
	Methanol/TBA (4.75%/4.75%)	0.49	0.40	0.89	90.6	0	33	-	13.6	-
II	Approved Lead, With MMT, Slate "A", ULR Only									
	Base Case	-	-	-	92.8	492	-	13.6	13.6	13.6
	Methanol/TBA (4.75%/4.75%)	0.40	0.72	1.12	91.6	0	33	-	13.6	-
	(5%/3%)	0.57	0.49	1.06	92.3	0	42	-	13.6	-
	(7%/3%)	0.42	0.71	1.13	90.7	0	35	-	13.6	-
	Methanol/IPA (4.75%/4.75%)	0.24	0.93	1.17	90.5	0	26	-	13.6	-
	(7%/3%)	0.28	0.89	1.17	90.5	0	28	-	13.6	-
	Methanol/IBA (4.75%/4.75%)	0.28	0.86	1.14	91.4	0	27	-	13.6	-
	(7%/3%)	0.39	0.74	1.13	91.1	0	33	-	13.6	-
	Methanol/Ethanol (5%/3%)	0.45	0.65	1.10	91.6	0	37	-	13.6	-
	Ethanol (10%)	0.13	1.06	1.19	91.6	0	20	-	13.6	-
	MTBE (11%)	(0.01)	1.21	1.20	90.2	0	9	-	13.6	-
	Toluene (9.2%)	(0.20)	1.39	1.19	92.8	0	1	-	13.6	-
	Sensitivity Cases(2)									
	Volatility:(2)									
	Methanol/TBA (4.75%/4.75%)	0.52	0.54	1.06	93.7	0	33	-	13.1	-
	(5%/3%)	0.57	0.46	1.03	92.6	0	42	-	13.6	-
	(7%/3%)	0.55	0.51	1.06	93.9	0	35	-	13.0	-
	Methanol/IPA (7%/3%)	0.63	0.42	1.05	94.2	0	28	-	11.9	-
	Methanol/IBA (7%/3%)	0.57	0.48	1.05	94.2	0	33	-	12.8	-
	Methanol/Ethanol (5%/3%), 150% off at 70°C	0.74	0.26	1.00	93.8	0	37	-	12.5	-
	125% off at 70°C	0.47	0.59	1.07	93.4	0	37	-	13.6	-
	Ethanol (10%)	0.74	0.30	1.04	94.2	0	20	-	10.5	-
	MTBE (11%)	0.00	1.19	1.19	91.7	0	9	-	13.6	-
	Octane:									
	Methanol/TBA (7%/3%), +4, (R+M)/2	0.49	0.61	1.10	93.6	0	35	-	13.3	-
	, -4, (R+M)/2	0.62	0.40	1.02	94.2	0	35	-	12.8	-
	MTBE (11%), +6, (R+M)/2	(0.02)	1.24	1.22	90.7	0	9	-	13.6	-
	, -6, (R+M)/2	0.02	1.12	1.14	92.9	0	9	-	13.5	-

Notes: (1) Volume of butane and crude reduction per volume of oxygenate use, compared with base case.
(2) All sensitivity cases computed using existing CGSB specifications for % off.

Cont'd.....

TABLE 9
(Continued)

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

REFINERY OPERATIONS SUMMARY

Case Number	Case Description/Oxygenates	Refinery Backout Ratios[1] Butane	Crude	Crude + Butane	Reformer Severity RON	Isomerization Capacity m^3/d	Oxygenate Blend	RVP, psia Leaded Regular	Unleaded Regular	Unleaded Premium
1	Reduced Lead, No MMT, Slate "A", ULR Only									
	Base Case	-	-	-	99.2	985	-	13.6	13.6	13.6
	Methanol/TBA (4.75%/4.75%)	0.34	0.98	1.32	94.5	951	33	-	13.6	-
	(5%/3%)	0.49	0.81	1.30	94.9	961	42	-	13.6	-
	Methanol/Ethanol (5%/3%)	0.39	0.95	1.34	94.4	957	37	-	13.6	-
	Ethanol (10%)	0.07	1.31	1.38	94.9	821	20	-	13.6	-
	MTBE (11%)	(0.10)	1.44	1.34	95.5	697	9	-	13.6	-
	Toluene (9.0%)	(0.26)	1.68	1.42	95.1	930	1	-	13.6	-
	Sensitivity Cases (Volatility)[2]									
	Methanol/TBA (4.75%/4.75%)	0.40	0.92	1.32	94.7	953	33	-	13.5	-
	(5%/3%)	0.54	0.77	1.31	94.9	962	42	-	13.6	-
	Methanol/Ethanol (5%/3%)	0.59	0.73	1.32	94.8	963	37	-	12.9	-
	Ethanol (10%)	0.59	0.69	1.28	96.6	799	20	-	11.1	-
	MTBE (11%)	(0.09)	1.45	1.36	94.5	839	9	-	13.6	-
2	Reduced Lead, With MMT, Slate "A", ULR Only									
	Base Case	-	-	-	95.8	975	-	13.6	13.6	13.6
	Methanol/TBA (4.75%/4.75%)	0.39	0.78	1.17	93.5	690	33	-	13.6	-
3	Reduced Lead, No MMT, Slate "A", All Grades									
	Base Case (see Case 1)									
	Methanol/TBA (4.75%/4.75%)	0.34	0.90	1.24	93.4	550	33	13.6	13.6	13.6
4	Reduced Lead, No MMT, Slate "B", ULR Only									
	Base Case	-	-	-	100.0	1,011	-	13.6	13.6	13.6
	Methanol/TBA (4.75%/4.75%)	0.25	1.10	1.35	95.9	812	33	-	13.6	-
	(5%/3%)	0.34	1.08	1.42	95.8	975	42	-	13.6	-
	Methanol/Ethanol (5%/3%)	0.24	1.15	1.39	96.0	781	37	-	13.6	-
5	Reduced Lead, With MMT, Slate "B", All Grades									
	Base Case	-	-	-	96.4	992	-	13.6	13.6	13.6
	Methanol/TBA (4.75%/4.75%)	0.45	0.64	1.09	93.6	300	33	13.6	13.6	13.6
	(5%/3%)	0.57	0.53	1.10	93.5	400	37	13.6	13.6	13.6
	Methanol/Ethanol (5%/3%)	0.49	0.61	1.10	93.4	350	42	13.6	13.6	13.6
	Ethanol (10%)	0.22	0.92	1.14	93.2	550	20	13.6	13.6	13.6
	MTBE (11%)	0.06	0.98	1.04	93.6	100	9	13.6	13.6	13.6
	Sensitivity Cases (Volatility)[2]									
	Methanol/TBA (4.75%/4.75%)	0.60	0.53	1.13	93.3	595	33	-	12.4	-
	(5%/3%)	0.61	0.51	1.12	93.2	520	37	-	13.3	-
	Methanol/Ethanol (5%/3%)	0.76	0.39	1.15	93.3	725	42	-	11.7	-
	Ethanol (10%)	0.79	0.35	1.14	93.3	685	20	-	8.6	-
	MTBE (11%)	0.05	1.03	1.08	93.4	440	9	-	13.6	-

Notes: (1) Volume of butane and crude reduction per volume of oxygenate use, compared with base case.
(2) All sensitivity cases computed using existing CGSB specifications for % off.

TABLE 9
(Continued)

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

REFINERY OPERATIONS SUMMARY

Case Number	Case Description/Oxygenates	Refinery Backout Ratios[1] Butane	Refinery Backout Ratios[1] Crude	Refinery Backout Ratios[1] Crude + Butane	Reformer Severity RON	Isomerization Capacity m^3/d	RVP, psia Oxygenate Blend	RVP, psia Leaded Regular	RVP, psia Unleaded Regular	RVP, psia Unleaded Premium
6	Reduced Lead, With MMT, Slate "B", All Grades, FEVI Specification									
	Base Case	-	-	-	96.4	1,011	-	13.6	12.2	11.5
	Methanol/TBA (4.75%/4.75%)	0.46	0.63	1.09	93.5	400	33	11.7	11.5	12.2
	Methanol/Ethanol (5%/3%)	0.60	0.51	1.11	93.5	450	37	11.9	11.7	10.8
	Ethanol (10%)	0.37	0.76	1.13	93.5	150	20	11.5	10.7	12.1
	MTBE (11%)	0.11	1.04	1.15	93.5	210	9	11.6	11.8	11.8
7	Reduced Lead, With MMT, Summer Slate & Volatility, All Grades									
	Base Case	-	-	-	96.1	1,024	-	11.5	11.5	11.5
	Methanol/TBA (4.75%/4.75%)	0.38	0.84	1.22	93.3	420	33	11.5	11.5	11.5
	(5%/3%)	0.54	0.66	1.20	93.4	520	47	11.5	11.5	11.5
	Methanol/Ethanol (5%/3%)	0.44	0.78	1.22	93.5	450	37	11.5	11.5	11.5
	Ethanol (10%)	0.31	1.00	1.31	93.3	660	20	11.5	10.0	11.5
	MTBE (11%)	(0.07)	1.36	1.29	93.4	170	9	11.5	11.5	11.5
8	Reduced Lead, With MMT, Winter Slate & Volatility, All Grades									
	Base Case	-	-	-	96.2	974	-	15.5	15.5	15.5
	Methanol/TBA (4.75%/4.75%)	0.46	0.61	1.07	93.3	250	33	15.5	15.5	15.5
	(5%/3%)	0.60	0.46	1.06	93.5	330	42	15.5	15.5	15.5
	Methanol/Ethanol (5%/3%)	0.52	0.56	1.08	93.4	280	37	15.5	15.5	15.5
	Ethanol (10%)	0.22	0.82	1.04	93.5	0	20	15.5	15.5	15.5
	MTBE (11%)	0.07	0.92	0.99	94.5	0	9	15.5	15.5	15.5
9	Approved Lead, With MMT, Hydrocracking Slate "A", ULR Only									
	Base Case	-	-	-	95.8	638	-	13.6	13.6	13.6
	Methanol/TBA (5%/3%)	0.52	0.46	0.98	95.8	270	42	-	13.6	-
	Methanol/Ethanol (5%/3%)	0.40	0.60	1.00	95.7	250	37	-	13.6	-
10	Reduced Lead, With MMT, Hydrocracking Slate "B", All Grades									
	Base Case	-	-	-	99.8	639	-	13.6	13.6	13.6
	Methanol/TBA (4.75%/4.75%)	0.26	1.01	1.27	94.2	603	33	13.6	13.6	13.6
	(5%/3%)	0.42	0.86	1.28	94.8	613	42	13.6	13.6	13.6
	Methanol/Ethanol (5%/3%)	0.34	0.99	1.33	94.3	609	37	13.6	13.6	13.6

Note: (1) Volume of butane and crude reduction per volume of oxygenate use, compared with base case.

Cont'd.....

TABLE 9
(Continued)

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

REFINERY OPERATIONS SUMMARY

Case Number	Case Description/Oxygenates	Refinery Backout Ratios (1) Butane	Refinery Backout Ratios (1) Crude	Refinery Backout Ratios (1) Crude + Butane	Reformer Severity RON	Isomerization Capacity m^3/d	Oxygenate Blend	RVP, psia Leaded Regular	RVP, psia Unleaded Regular	RVP, psia Unleaded Premium
	BRITISH COLUMBIA									
11	Approved Lead, With MMT, Slate "A", ULR Only									
	Base Case	-	-	-	93.3	130	-	13.6	13.6	13.6
	Methanol/Ethanol (5%/3%)	0.44	0.77	1.21	90.3	0	37	-	13.6	-
	PRAIRIES									
12A	Approved Lead, With MMT, Average Slate "A", ULR Only									
	Base Case	-	-	-	91.1	0	-	13.6	13.6	13.6
	Methanol/Ethanol (5%/3%)	0.41	0.63	1.04	90.0	0	37	-	13.6	-
	Methanol/TBA (5%/3%)	0.53	0.52	1.05	90.0	0	42	-	13.6	-
	MTBE (11%)	(0.16)	1.14	0.98	90.0	0	9	-	13.6	-
12B	Reduced Lead, With MMT, Average Slate "B", All Grades									
	Base Case	-	-	-	97.8	300	-	13.6	13.6	13.6
	Methanol/Ethanol (5%/3%)	0.44	0.65	1.09	94.3	0	37	13.6	13.6	13.6
	Methanol/TBA (5%/3%)	0.55	0.53	1.08	94.8	0	42	13.6	13.6	13.6
	MTBE (11%)	(0.15)	1.18	1.02	91.9	0	9	13.6	13.6	13.6
12C	Reduced Lead, With MMT, Summer Slate, All Grades									
	Base Case	-	-	-	97.9	300	-	11.5	11.5	11.5
	Methanol/Ethanol (5%/3%)	0.47	0.65	1.12	95.9	0	37	11.5	11.1	11.5

Note: (1) Volume of butane and crude reduction per volume of oxygenate use, compared with base case.

Cont'd.....

TABLE 9
(Continued)

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

REFINERY OPERATIONS SUMMARY

Case Number	Case Description/Oxygenates	Refinery Backout Ratios[1] Butane	Crude	Crude + Butane	Reformer Severity RON	Isomerization Capacity m^3/d	RVP, psia Oxygenate Blend	Leaded Regular	Unleaded Regular	Unleaded Premium
	QUEBEC AND ATLANTIC									
13A	Approved Lead, With MMT, Average Slate "A", ULR Only									
	Base Case	-	-	-	93.8	400	-	13.6	13.6	13.6
	Methanol/Ethanol (5%/3%)	0.49	0.48	0.97	93.7	200	37	-	13.6	-
	Methanol/TBA (5%/3%)	0.58	0.39	0.97	93.7	230	42	-	13.6	-
	MTBE (11%)	(0.12)	1.20	1.08	93.3	120	9	-	13.6	-
13B	Reduced Lead, With MMT, Average Slate "B", All Grades									
	Base Case	-	-	-	95.4	796	-	13.6	13.6	13.6
	Methanol/Ethanol (5%/3%)	0.35	0.72	1.07	93.6	500	37	13.6	13.6	13.6
	Methanol/TBA (5%/3%)	0.44	0.62	1.06	93.8	540	42	13.6	13.6	13.6
	MTBE (11%)	(0.17)	1.21	1.04	93.7	240	9	13.6	13.6	13.6
13C	Reduced Lead With MMT, Summer Slate, All Grades									
	Base Case	-	-	-	95.7	814	-	11.5	11.5	11.5
	Methanol/Ethanol (5%/3%)	0.40	0.85	1.25	92.0	774	37	11.5	11.5	11.5

Note: (1) Volume of butane and crude reduction per volume of oxygenate use, compared with base case.

TABLE 10

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

CAPITAL AND FIXED COST BASIS
(1985 Dollars)

Item	Unit	Capacity (m^3/d)	Capital (10^6\$)	Capital Recovery (M\$/d) (1)	Fixed Operating Costs (M\$/d)	Total Fixed and Capital Costs (M\$/d)
1	Oxygenate Offsites	<820	1.8	1.2	-	1.2
2	Isomerization(2)	160	5.3	3.7	3.9	7.6
3	Isomerization(2)	490	11.2	7.7	5.1	12.8
4	Isomerization(2)	985	17.8	12.2	6.3	18.5
5	Catalytic Reformer Catalyst(3)	3,000	3.0	2.1	-	2.1
6	Catalytic Reformer Moderate Revamp(3)	3,000	14.6	10.0	-	10.0
7	Catalytic Reformer Extensive Revamp(3)	3,000	30.2	20.7	-	20.7

Notes: (1) Capital recovery = 25% per year of capital cost.
(2) Isomerization cost varies with capacity of unit. Cost for other capacities were interpolated or extrapolated from these three units.
(3) Reformer capital costs based on severity needs (RON):

	Existing Maximum Capability	With New Catalyst Only	With Moderate Revamp	With Extensive Revamp
Ontario-FCC, British Columbia	93.5	93.6- 96.0	96.1- 97.5	97.6+
Ontario-Hydrocracking	96.0	96.1- 98.5	98.6-100.0	100.1+
Prairies	98.0	98.1-100.5	100.6+	-
Quebec/Atlantic	94.5	94.6- 97.0	97.1- 98.5	98.6+

TABLE 11

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

CAPITAL AND FIXED COST ESTIMATES

Items[1]	Case	Capital ($10^6$$)	Capital Recovery (M$/d) [2]	Fixed Operating Costs (M$/d)	Total Fixed and Capital Costs (M$/d)
	ONTARIO				
	I - 1985 Markets				
-	Base	0	0	0	0
1	Oxygenates	1.8	1.2	0	1.2
	II - Approved Lead, With MMT, Slate "A", ULR Only				
3	Base	11.2	7.7	5.1	12.8
1	Oxygenates	1.8	1.2	0	1.2
-	Toluene	0	0	0	0
	1 - Reduced Lead, No MMT, Slate "A", ULR Only				
4+7	Base	48.0	32.9	6.3	39.2
1+4+5	Oxygenates	22.2	15.2	6.2	21.4
4+5	Toluene	19.6	13.4	6.2	19.6
	2 - Reduced Lead, With MMT, Slate "A", ULR Only				
4+5	Base	20.9	14.3	6.3	20.6
1+3	Methanol/TBA (4.75%/4.75%	15.5	10.6	5.7	16.3
	3 - Reduced Lead, No MMT, Slate "A", All Grades				
4+7	Base	48.0	32.9	6.3	39.2
1+3	Methanol/TBA (4.75%/4.75%)	13.9	9.5	5.2	14.7
	4 - Reduced Lead, No MMT, Slate "B", ULR Only				
4+7	Base	48.5	33.2	6.4	39.6
1+4+5	Oxygenates[3]	19.9	13.6	5.9	19.5
	5 - Reduced Lead, With MMT, Slate "B", All Grades				
4+6	Base	32.7	22.4	6.3	28.7
1+3	Alcohols[3]	10.5	7.2	4.5	11.7
1+2	MTBE (11%)	6.1	4.2	3.7	7.9

Notes: (1) See Table 10. Isomerization capital cost is Item 2, 3 or 4, depending on required capacity.
(2) Capital recovery = 25% per year of capital cost.
(3) Example for methanol/ethanol (5%/3%). Capital cost of other oxygenates varies for isomerization capacity.

Cont'd.....

TABLE 11
(Continued)

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

CAPITAL AND FIXED COST ESTIMATES

Items(1)	Case	Capital ($10^6$$)	Capital Recovery (M$/d) (2)	Fixed Operating Costs (M$/d)	Total Fixed and Capital Costs (M$/d)
	ONTARIO				
	6 - Reduced Lead, With MMT, Slate "B", All Grades, FEVI Specs.				
4+6	Base	32.8	22.5	6.4	28.9
1+3	Alcohol Blends(3)	12.3	8.4	4.9	13.3
1+2	Ethanol (10%), MTBE (11%)(4)	7.9	5.4	4.0	9.4
	7 - Reduced Lead, With MMT, Summer Slate & Volatility, All Grades				
4+6	Base	32.9	22.5	6.5	29.0
1+3	Alcohols(3)	12.3	8.4	4.9	13.3
1+2	MTBE (11%)	7.4	5.1	3.9	9.0
	8 - Reduced Lead, With MMT, Winter Slate & Volatility, All Grades				
4+5	Base	20.9	14.3	6.3	20.6
1+2	Alcohol Blends(3)	9.5	6.5	4.3	10.8
1	Ethanol (10%)	1.8	1.2	0	1.2
1+5	MTBE (11%)	4.8	3.3	0	3.3
	9 - Approved Lead, With MMT, Hydrocracking Slate "A", ULR Only				
3	Base	13.3	9.1	5.5	14.6
1+2	Oxygenates(3)	8.9	6.1	4.1	10.2
	10 - Reduced Lead, With MMT, Hydrocracking Slate "B", All Grades				
3+6	Base	27.9	19.1	5.5	24.6
1+3	Oxygenates(3)	14.6	10.0	5.4	15.4

Notes: (1) See Table 10. Isomerization capital cost is Item 2, 3 or 4, depending on required capacity.
(2) Capital recovery = 25% per year of capital cost.
(3) Example for methanol/ethanol (5%/3%). Capital cost of other oxygenates varies for isomerization capacity.
(4) MTBE (11%) shown. Ethanol (10%) capital cost varies for isomerization capacity.

Cont'd.....

TABLE 11
(Continued)

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

CAPITAL AND FIXED COST ESTIMATES

Items(1)	Case	Capital ($10^6$$)	Capital Recovery (M$/d) (2)	Fixed Operating Costs (M$/d)	Total Fixed and Capital Costs (M$/d)
	BRITISH COLUMBIA				
	11 - Approved Lead, With MMT, Slate "A", ULR Only				
2	Base	5.0	3.4	3.7	7.1
1	Methanol/Ethanol (5%/3%)	1.8	1.2	0	1.2
	PRAIRIES				
	12A - Approved Lead, With MMT, Average Slate "A", ULR Only				
-	Base	0	0	0	0
1	Oxygenates	1.9	1.3	0	1.3
	12B - Reduced Lead, With MMT, Average Slate "B", All Grades				
2	Base	9.6	6.6	4.5	11.1
1	Oxygenates	1.9	1.3	0	1.3
	12C - Reduced Lead, With MMT, Summer Slate, All Grades				
2	Base	9.6	6.6	4.5	11.1
1	Methanol/Ethanol (5%/3%)	1.9	1.3	0	1.3
	QUEBEC AND ATLANTIC				
	13A - Approved Lead, With MMT, Average Slate "A", ULR Only				
3	Base	11.5	7.9	5.1	13.0
1+2	Oxygenates(3)	7.7	5.3	4.0	9.3
	13B - Reduced Lead, With MMT Average Slate "B", All Grades				
4+5	Base	18.4	12.6	5.9	18.5
1+3	Alcohol Blends(3)	13.3	9.1	5.1	14.2
1+2	MTBE (11%)	8.8	6.0	4.1	10.1
	13C - Reduced Lead, With MMT, Summer Slate, All Grades				
4+5	Base	18.5	12.7	6.0	18.7
1+5	Methanol/Ethanol (5%/3%)	16.4	11.2	5.9	17.4

Notes: (1) See Table 10. Isomerization capital cost is Item 2.3 or 4, depending on required capacity.
(2) Capital recovery = 25% per year of capital cost.
(3) Example for methanol/ethanol (5%/3%). Capital cost of other oxygenates varies for isomerization capacity.

TABLE 12

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ECONOMIC RESULTS

Case Number	Case Description/Oxygenates	Refinery Breakeven Value ¢/L	Estimated Cost Supply ¢/L	Refinery Margin ¢/L of Oxygenate	Refinery Margin ¢/L of Oxygenated Gasoline
	ONTARIO				
I	1985 Market, ULR Only				
	Methanol/TBA (4.75%/4.75%) Gasoline Yield Sensitivity	26.5	29.5	(3.0)	(0.3)
	Methanol/IPA (4.75%/4.75%)	28.8	32.7	(3.9)	(0.4)
	Methanol/IBA (4.75%/4.75%)	27.9	33.0	(5.1)	(0.5)
	Methanol/Ethanol (5%/3%)	27.0	23.9	3.1	0.2
	Ethanol (10%)	27.7	33.9	(6.2)	(0.6)
	MTBE (11%)	30.2	40.0	(9.8)	(1.1)
	Sensitivity Case (Gasoline Yield) Methanol/TBA (4.75%/4.75%)	27.9	29.5	(1.6)	(0.2)
II	Approved Lead, With MMT, Slate "A", ULR Only				
	Methanol/TBA (4.75%/4.75%)	23.9	23.7	0.2	0.0
	(5%/3%)	22.6	21.5	1.1	0.1
	(7%/3%)	24.2	20.3	3.9	0.4
	Methanol/IPA (4.75%/4.75%)	26.0	27.5	(1.5)	(0.1)
	(7%/3%)	25.5	22.6	2.9	0.3
	Methanol/IBA (4.75%/4.75%)	25.1	28.0	(2.9)	(0.3)
	(7%/3%)	24.3	22.9	1.4	0.1
	Methanol/Ethanol (5%/3%)	24.2	21.9	2.3	0.2
	Ethanol (10%)	26.6	33.0	(6.4)	(0.6)
	MTBE (11%)	27.1	27.6	(0.5)	(0.1)
	Toluene (9.2%)	29.4	30.5	(1.1)	(0.1)
	Sensitivity Cases(1)				
	Volatility(1)				
	Methanol/TBA (4.75%/4.75%)	21.6	23.7	(2.1)	(0.2)
	(5%/3%)	22.2	21.5	0.7	0.1
	(7%/3%)	21.4	20.3	1.1	0.1
	Methanol/IPA (7%/3%)	20.9	22.6	(1.7)	(0.2)
	Methanol/IBA (7%/3%)	21.1	22.9	(1.8)	(0.2)
	Methanol/Ethanol (5%/3%),				
	150% off at 70°C	20.0	21.9	(1.9)	(0.2)
	125% off at 70°C	22.5	21.9	0.6	0.0
	Ethanol (10%)	20.1	33.0	(12.9)	(1.3)
	MTBE (11%)	26.7	27.6	(0.9)	(0.1)
	Octane				
	Methanol/TBA (7%/3%), +4, (R+M)/2	22.6	20.3	2.3	0.2
	-4, (R+M)/2	20.3	20.3	0.0	0.0
	MTBE (11%), +6,(R+M)/2	27.5	27.6	(0.1)	0.0
	-6,(R+M)/2	25.8	27.6	(1.8)	(0.2)

Note: (1) All sensitivity cases computed using existing volatility specifications

Cont'd.....

TABLE 12
(Continued)

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ECONOMIC RESULTS

Case Number	Case Description/Oxygenates	Refinery Breakeven Value ¢/L	Estimated Cost Supply ¢/L	Refinery Margin ¢/L of Oxygenate	Refinery Margin ¢/L of Oxygenated Gasoline
1	Reduced Lead, No MMT, Slate "A", ULR Only				
	Methanol/TBA (4.75%/4.75%)	29.5	23.7	5.8	0.6
	(5%/3%)	29.3	21.5	7.8	0.6
	Methanol/Ethanol (5%/3%)	30.5	21.9	8.6	0.7
	Ethanol (10%)	32.1	33.0	(0.9)	(0.1)
	MTBE (11%)	32.0	27.6	4.4	0.5
	Toluene (9.0%)	35.0	30.5	4.5	0.4
	Sensitivity Cases(1) Volatility(1)				
	Methanol/TBA (4.75%/4.75%)	28.8	23.7	5.1	0.5
	(5%/3%)	28.8	21.5	7.3	0.6
	Methanol/Ethanol (5%/3%)	28.6	21.9	6.7	0.5
	Ethanol (10%)	25.4	33.0	(7.6)	(0.8)
	MTBE (11%)	32.1	27.6	4.5	0.4
2	Reduced Lead, With MMT, Slate "A", ULR Only				
	Methanol/TBA (4.75%/4.75%)	23.4	23.7	(0.3)	0.0
3	Reduced Lead, No MMT, Slate "A", All Grades				
	Methanol/TBA (4.75%/4.75%)	27.6	23.7	3.9	0.4
4	Reduced Lead, No MMT, Slate "B", ULR Only				
	Methanol/TBA (4.75%/4.75%)	30.6	23.7	6.9	0.7
	(5%/3%)	31.9	21.5	10.4	0.8
	Methanol/Ethanol (5%/3%)	32.5	21.9	10.6	0.8
5	Reduced Lead, With MMT, Slate "B", All Grades				
	Methanol/TBA (4.75%/4.75%)	23.2	23.7	(0.5)	(0.1)
	(5%/3%)	23.0	21.5	1.5	0.1
	Methanol/Ethanol (5%/3%)	23.7	21.9	1.8	0.1
	Ethanol (10%)	25.1	33.0	(7.9)	(0.8)
	MTBE (11%)	24.9	27.6	(2.7)	(0.3)
	Sensitivity Cases(1) Volatility(1)				
	Methanol/TBA (4.75%/4.75%)	22.4	23.7	(1.3)	(0.1)
	(5%/3%)	22.9	21.5	1.4	0.1
	Methanol/Ethanol (5%/3%)	22.2	21.9	0.3	0.0
	Ethanol (10%)	21.5	33.0	(11.5)	(1.1)
	MTBE (11%)	25.1	27.6	(2.5)	(0.3)

Note: (1) All sensitivity cases computed using existing volatility specifications.

Cont'd.....

TABLE 12
(Continued)

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ECONOMIC RESULTS

Case Number	Case Description/Oxygenates	Refinery Breakeven Value ¢/L	Estimated Cost Supply ¢/L	Refinery Margin ¢/L of Oxygenate	Refinery Margin ¢/L of Oxygenated Gasoline
6	Reduced Lead, With MMT, Slate "B", All Grades, FEVI Specification				
	Methanol/TBA (4.75%/4.75%)	23.5	23.7	(0.2)	0.0
	Methanol Ethanol (5%/3%)	23.1	21.9	1.2	0.1
	Ethanol (10%)	24.5	33.0	(8.5)	(0.8)
	MTBE (11%)	25.6	27.6	(2.0)	(0.2)
7	Reduced Lead, With MMT, Summer Slate & Volatility, All Grades				
	Methanol/TBA (4.75%/4.75%)	24.8	23.7	1.1	0.1
	(5%/3%)	23.9	21.5	2.4	0.2
	Methanol/Ethanol (5%/3%)	24.8	21.9	2.9	0.3
	Ethanol (10%)	26.2	33.0	(6.8)	(0.7)
	MTBE (11%)	28.5	27.6	0.9	0.1
8	Reduced Lead, With MMT, Winter Slate & Volatility, All Grades				
	Methanol/TBA (4.75%/4.75%)	21.7	23.7	(2.0)	(0.2)
	(5%/3%)	21.0	21.5	(0.5)	0.0
	Methanol/Ethanol (5%/3%)	21.7	21.9	(0.2)	0.0
	Ethanol (10%)	24.1	33.0	(8.9)	(0.9)
	MTBE (11%)	23.9	27.6	(3.7)	(0.4)
9	Approved Lead, With MMT, Hydrocracking Slate "A", ULR Only				
	Methanol/TBA (5%/3%)	20.7	21.5	(0.8)	(0.1)
	Methanol/Ethanol (5%/3%)	22.0	21.9	0.1	0.0
10	Reduced Lead, With MMT, Hydrocracking Slate "B", All Grades				
	Methanol/TBA (4.75%/4.75%)	28.3	23.7	4.6	0.4
	(5%/3%)	27.8	21.5	6.3	0.5
	Methanol/Ethanol (5%/3%)	29.1	21.9	7.2	0.6

Note: (1) All sensitivity cases computed using existing volatility specifications.

Cont'd.....

TABLE 12
(Continued)

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ECONOMIC RESULTS

Case Number	Case Description/Oxygenates	Refinery Breakeven Value ¢/L	Estimated Cost Supply ¢/L	Refinery Margin ¢/L of Oxygenate	Refinery Margin ¢/L of Oxygenated Gasoline
	BRITISH COLUMBIA				
11A	Approved Lead, With MMT, Slate "A", ULR Only				
	Methanol/Ethanol (5%/3%)				
	(B.C. Gasoline Grade Split)	24.6	20.9	3.7	0.3
	(Ontario Gasoline Grade Split)	23.5	20.9	2.6	0.2
	Methanol/TBA (5%/3%)	21.7	19.8	1.9	0.2
	MTBE (11%)	26.9	25.2	1.7	0.2
11B	Reduced Lead, With MMT, Average Slate "B", All Grades				
	Methanol/Ethanol (5%/3%)	22.9	20.9	2.0	0.2
	Methanol/TBA (5%/3%)	22.1	19.8	2.3	0.2
	MTBE (11%)	24.8	25.2	(0.4)	0.0
11C	Reduced Lead, With MMT, Summer Slate "B", All Grades				
	Methanol/Ethanol (5%/3%)	22.7	20.9	1.8	0.1
	PRAIRIES				
12A	Approved Lead, With MMT, Average Slate "A", ULR Only				
	Methanol/Ethanol (5%/3%)	19.5	20.4	(0.9)	(0.1)
	Methanol/TBA (5%/3%)	18.3	17.8	0.5	0.0
	MTBE (11%)	24.1	23.2	0.9	0.1
12B	Reduced Lead, With MMT, Average Slate "B", All Grades				
	Methanol/Ethanol (5%/3%)	22.1	20.4	1.7	0.1
	Methanol/TBA (5%/3%)	20.9	17.8	3.1	0.2
	MTBE (11%)	26.6	23.2	3.4	0.4
12C	Reduced Lead, With MMT, Summer Slate, All Grades				
	Methanol/Ethanol (5%/3%)	20.8	20.4	0.4	0.0

Note: (1) All sensitivity cases computed using existing volatility specifications.

Cont'd.....

TABLE 12
(Continued)

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ECONOMIC RESULTS

Case Number	Description/Oxygenates	Refinery Breakeven Value ¢/L	Estimated Cost Supply ¢/L	Refinery Margin ¢/L of Oxygenate	Refinery Margin ¢/L of Oxygenated Gasoline
	QUEBEC				
13A	Approved Lead, With MMT, Average Slate "A", ULR Only				
	Methanol/Ethanol (5%/3%)	20.7	22.0	(1.3)	(0.1)
	Methanol/TBA (5%/3%)	19.7	22.0	(2.3)	(0.2)
	MTBE (11%)	25.3	28.1	(2.8)	(0.3)
13B	Reduced Lead, With MMT, Average Slate "B", All Grades				
	Methanol/Ethanol (5%/3%)	23.6	22.0	1.6	0.1
	Methanol/TBA (5%/3%)	22.9	22.0	0.9	0.1
	MTBE (11%)	25.5	28.1	(2.6)	(0.3)
13C	Reduced Lead, With MMT, Summer Slate, All Grades				
	Methanol/Ethanol (5%/3%)	24.3	22.0	2.3	0.2
	ATLANTIC				
14A	Approved Lead, With MMT, Average Slate "A", ULR Only				
	Methanol/Ethanol (5%/3%)	19.4	22.3	(2.9)	(0.2)
	Methanol/TBA (5%/3%)	18.5	23.3	(4.8)	(0.4)
	MTBE (11%)	24.1	29.4	(5.3)	(0.6)
14B	Reduced Lead, With MMT, Average Slate "B", All Grades				
	Methanol/Ethanol (5%/3%)	23.1	22.3	0.8	0.1
	Methanol/TBA (5%/3%)	22.4	23.3	(0.9)	(0.1)
	MTBE (11%)	24.8	29.4	(4.6)	(0.5)
14C	Reduced Lead, With MMT, Summer Slate, All Grades				
	Methanol/Ethanol (5%/3%)	23.8	22.3	1.5	0.1

Note: (1) All sensitivity cases computed using existing volatility specifications.

TABLE 13

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

CANADIAN REFINING SUMMARY
(Thousands of Cubic Metres per Day, Unless Noted)

	British Columbia	Prairies	Ontario	Quebec	Atlantic	CANADA
Refinery Crude Capacity	26.4	71.3	80.2	53.8	35.7	267.4
1985 Forecast						
Crude Throughput	22.8	50.3	77.0	47.7	26.9	225.7
Refinery Utilization, %	86	71	96	75	75	81
Gasoline Production						
- Regular Leaded	5.86	14.22	14.47	7.61	3.46	45.62
- Regular Unleaded	2.84	7.57	14.48	6.34	3.22	34.45
- Premium Unleaded	0.76	1.15	2.52	1.90	0.53	6.86
Total	9.46	22.94	31.47	15.85	7.21	86.93
Regular Unleaded, % Gasoline	30	33	46	40	46	40
1990 Forecast						
Crude Throughput	23.6	51.6	70.6	44.0	24.8	214.6
Refinery Utilization, %	89	72	88	82	69	80
Gasoline Production, 0.29 g Pb/L						
- Regular Leaded	4.63	11.93	8.68	4.21	2.00	31.45
- Regular Unleaded	4.26	10.09	17.94	8.13	4.14	44.56
- Premium Unleaded	0.76	0.92	2.32	1.68	0.53	6.21
Total	9.65	22.94	28.94	14.02	6.67	82.22
Regular Unleaded, % Gasoline	44	44	62	58	62	54
Gasoline Production, 0.027 g Pb/L						
- Regular Leaded	1.45	3.43	2.89	1.40	0.67	9.84
- Regular Unleaded	6.75	16.08	20.27	9.82	4.66	57.58
- Premium Unleaded	1.45	3.43	5.78	2.80	1.34	14.80
Total	9.65	22.94	28.94	14.02	6.67	82.22
Regular Unleaded, % Gasoline	70	70	70	70	70	70

FIGURES

F I G U R E 1

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

GENERALIZED REFINERY BLOCK FLOW DIAGRAM

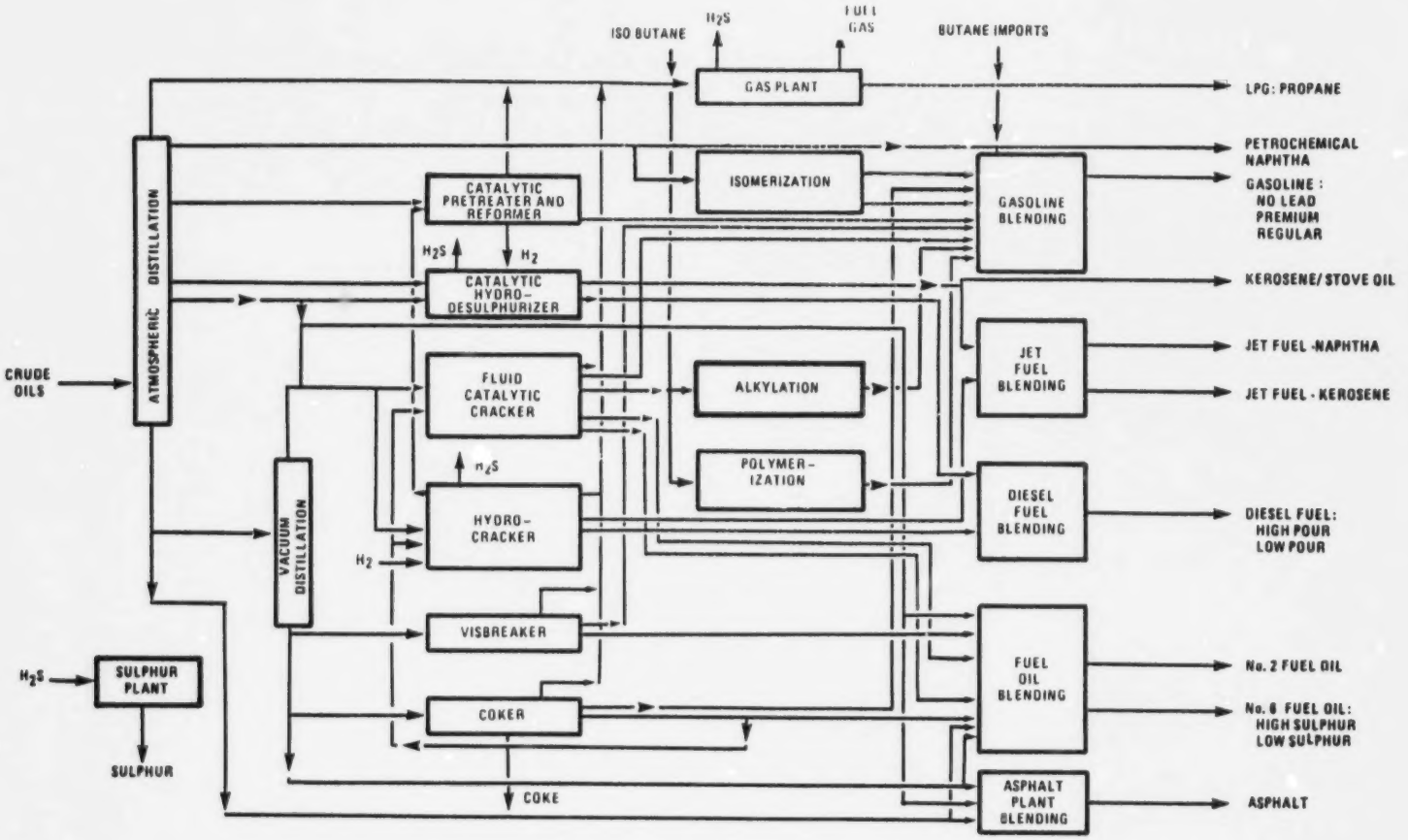
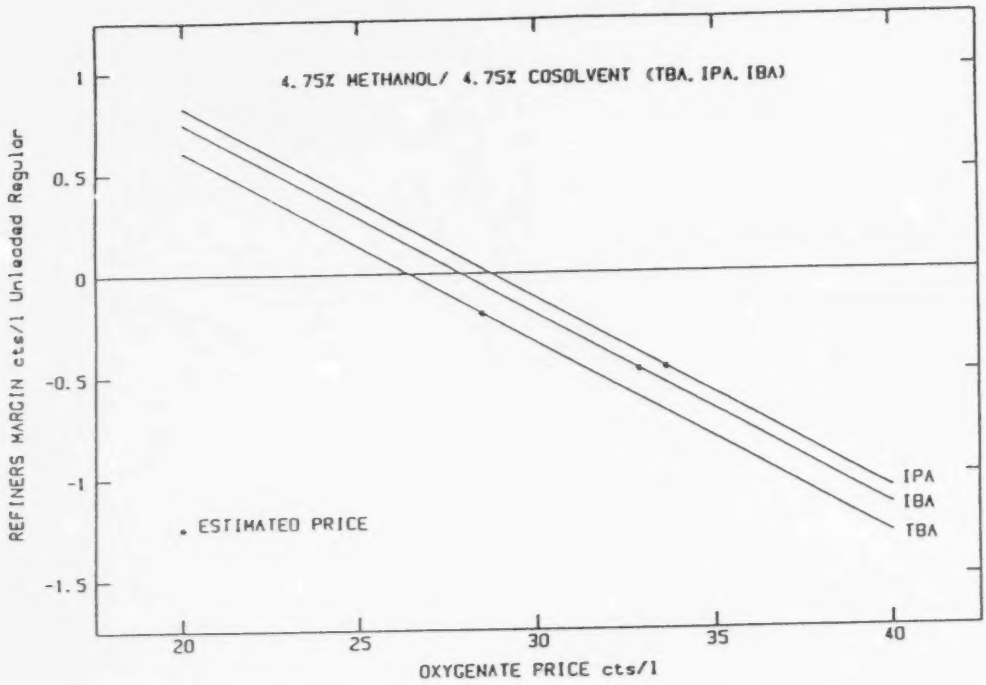


FIGURE 2

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

REFINER'S MARGIN VERSUS OXYGENATE PRICE
ONTARIO - 1985 - CASE I



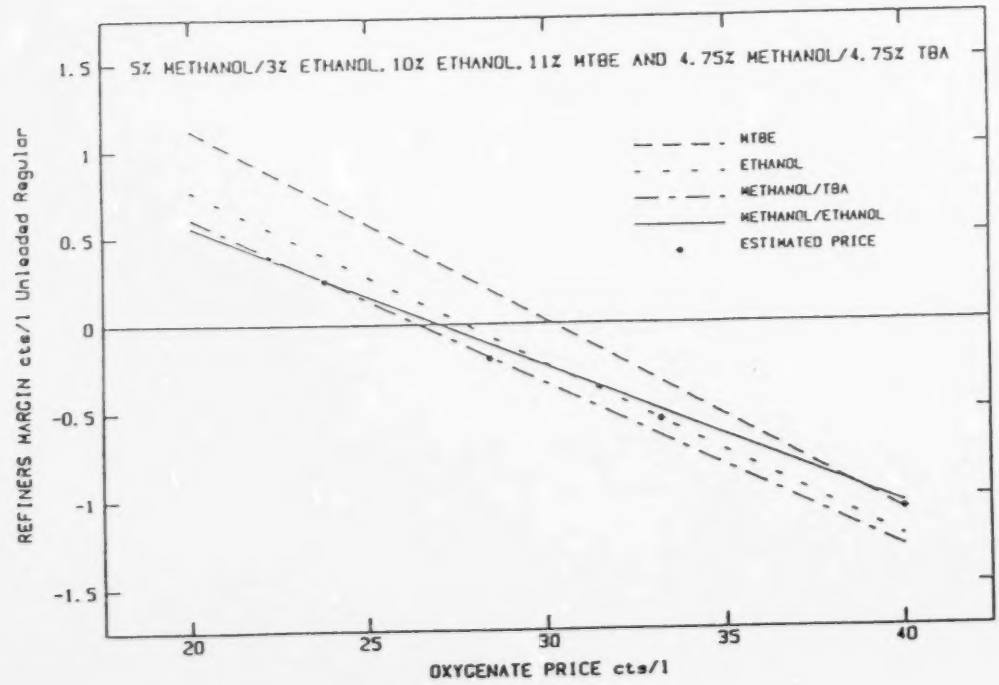
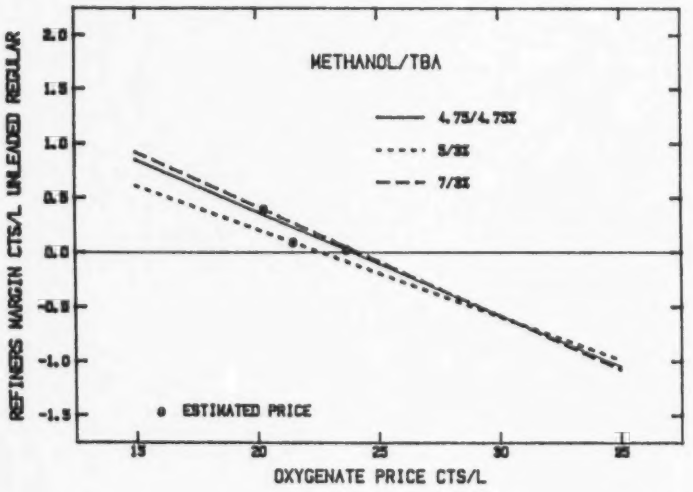
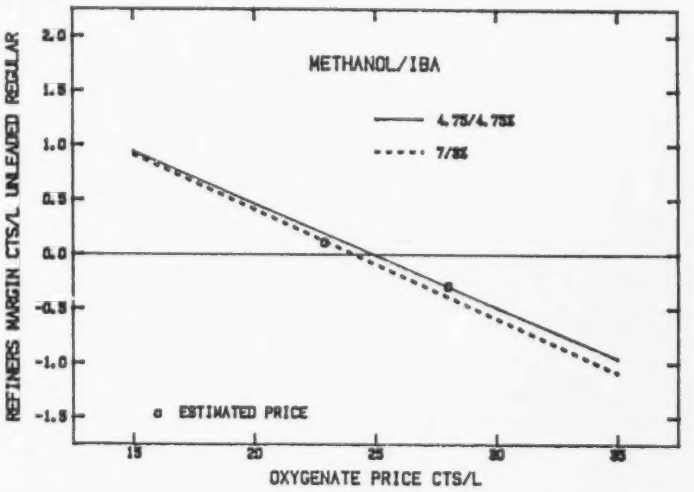


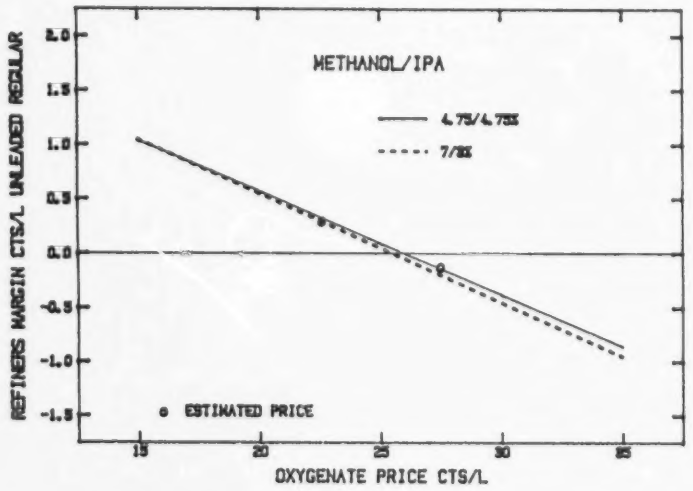
FIGURE 3

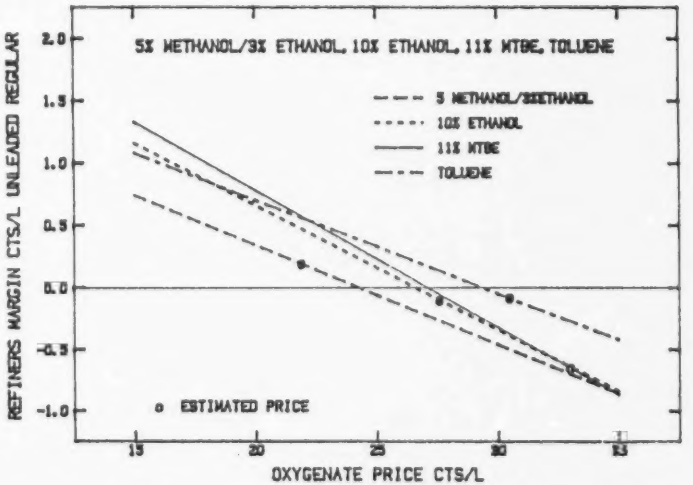
ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

REFINER'S MARGIN VERSUS OXYGENATE PRICE
ONTARIO - 1990 APPROVED LEAD LEVEL - CASE II





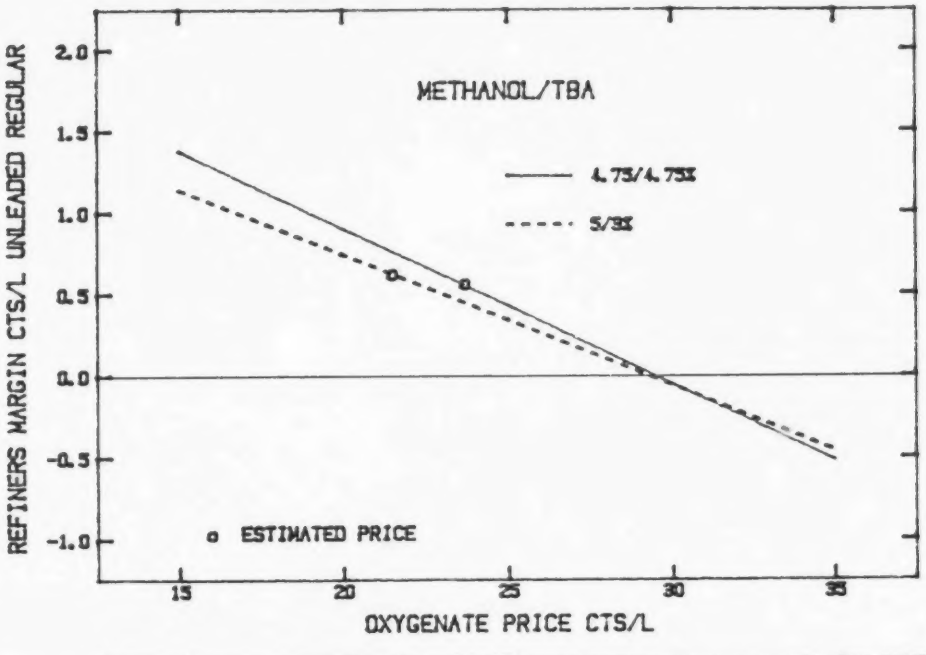




F I G U R E 4

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

REFINER'S MARGIN VERSUS OXYGENATE PRICE
ONTARIO - 1990 REDUCED LEAD LEVEL - CASE 1



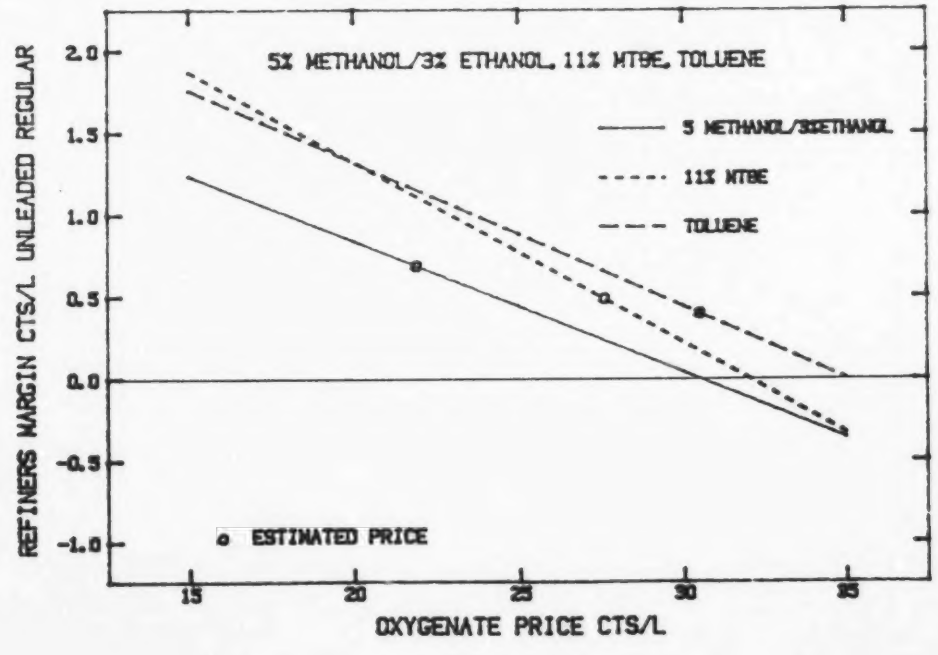
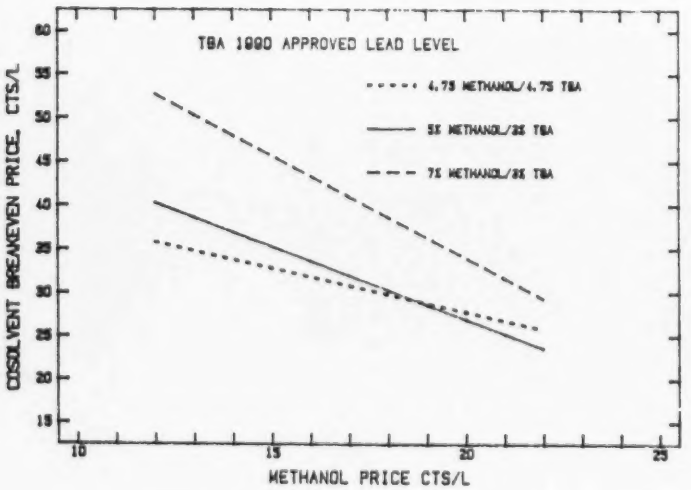
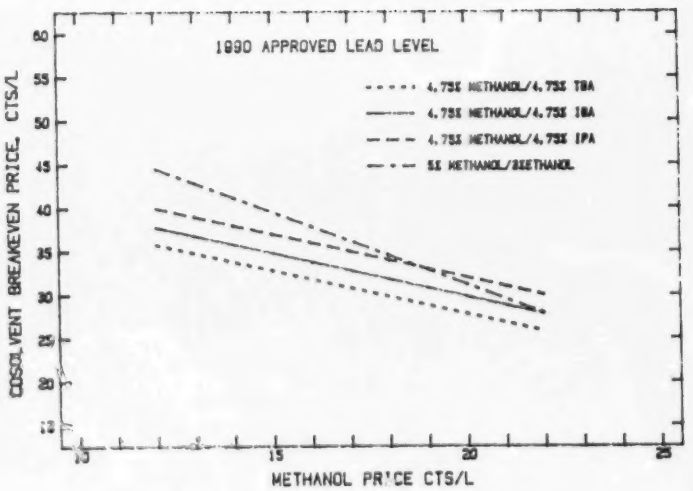


FIGURE 5

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

METHANOL PRICE SENSITIVITY - ONTARIO





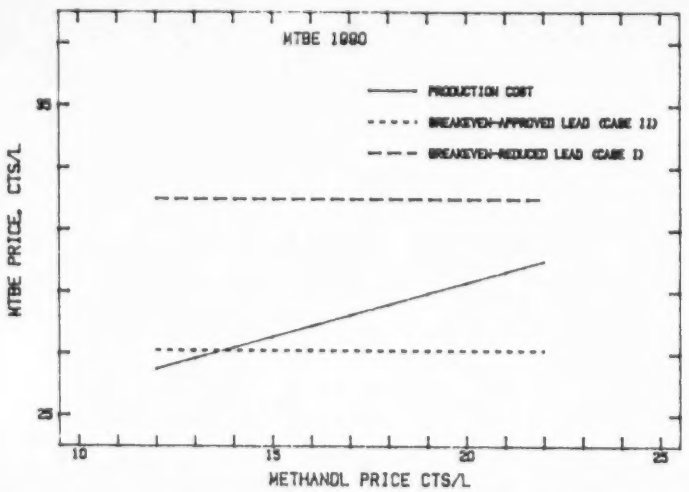
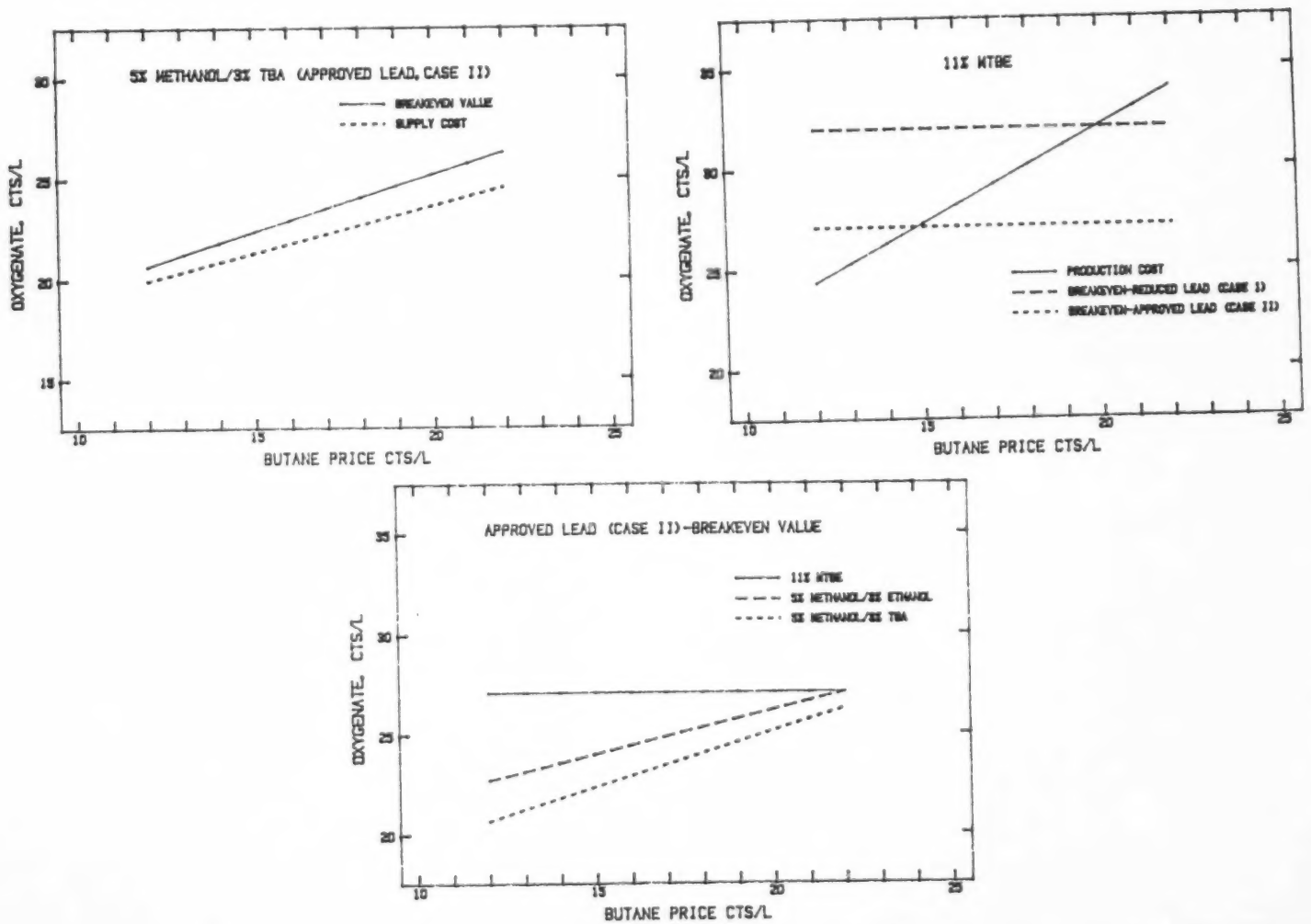


FIGURE 6

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

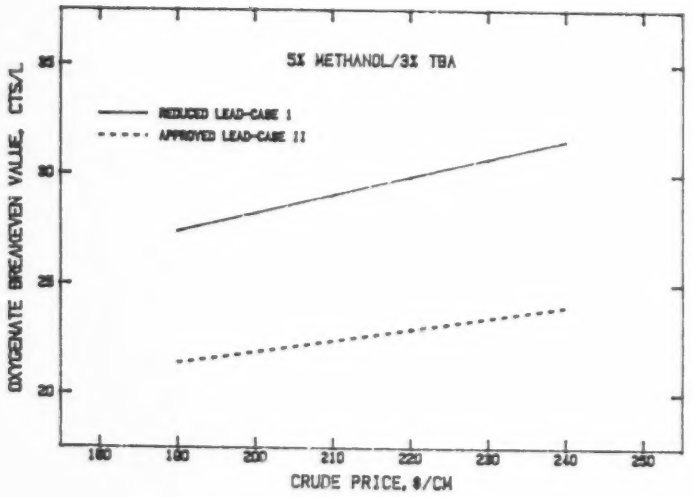
NORMAL BUTANE PRICE SENSITIVITY - ONTARIO, 1990

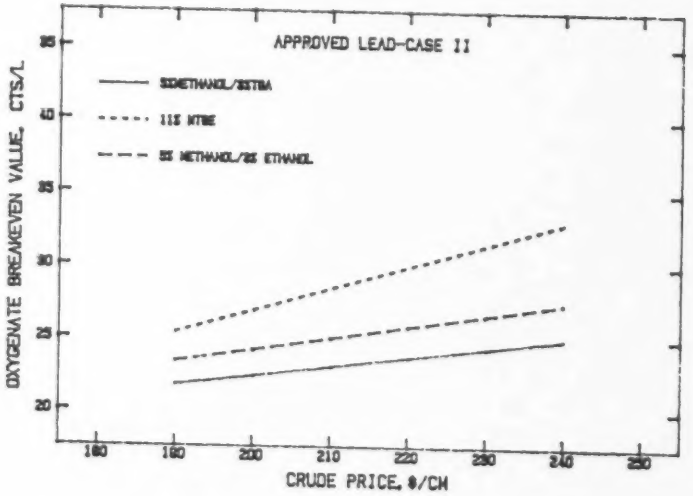


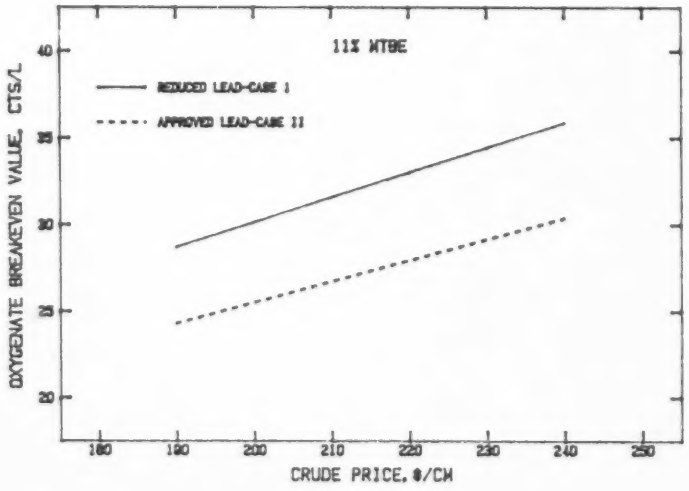
F I G U R E 7

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

CRUDE PRICE SENSITIVITY - ONTARIO, 1990



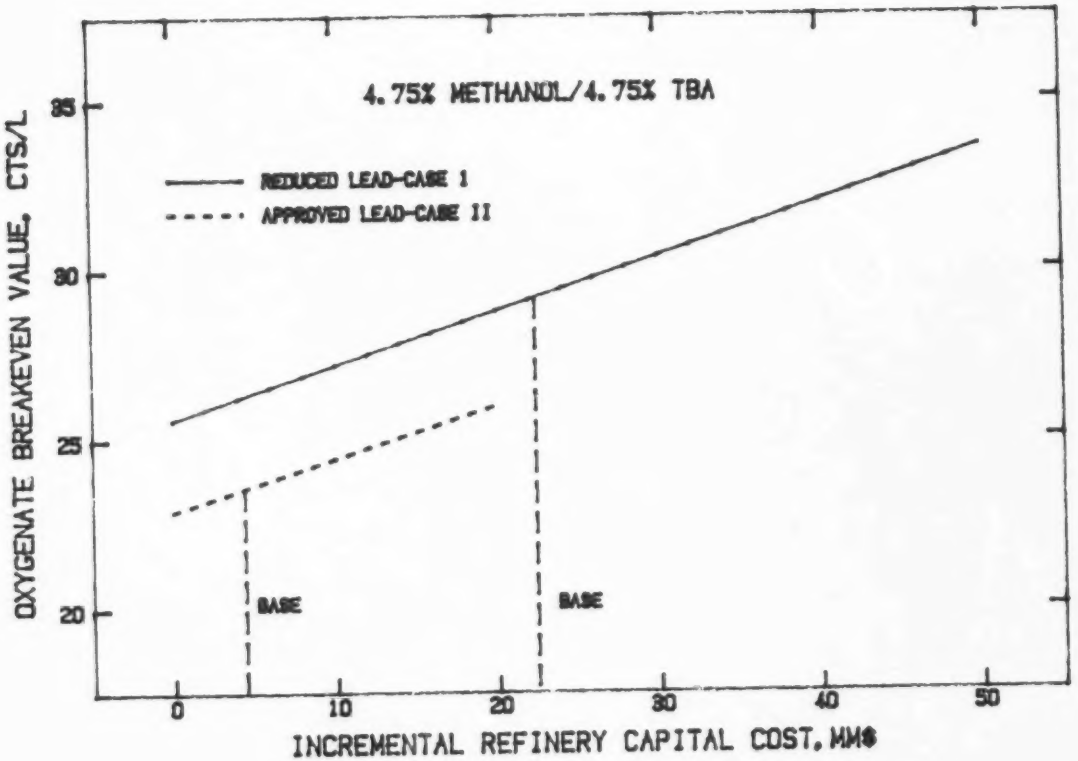




F I G U R E 8

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

CAPITAL COST SENSITIVITY - ONTARIO, 1990



APPENDIX

APPENDIX - LIST OF TABLES

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A-3	Ontario Economics - Case I Methanol/TBA in ULR Gasoline with Yield Sensitivity 1985 Market
A-4	Ontario Economics - Case II Methanol/TBA in ULR Gasoline Approved Lead, with MMT, Product Slate "A"
A-5	Ontario Economics - Case II Methanol/IPA in ULR Gasoline Approved Lead, with MMT, Product Slate "A"
A-6	Ontario Economics - Case II Methanol/IBA and Toluene in ULR Gasoline Approved Lead, with MMT, Product Slate "A"
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A-22	Ontario Economics - Hydrocracking Refinery - Case 10 Methanol/Cosolvents (TBA and Ethanol) in all Gasoline Grades Reduced Lead, with MMT, Product Slate "B"
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C-1	Prairie Economics - Case 12A Methanol/Cosolvent (TBA and Ethanol) and MTBE in ULR Gasoline Approved Lead, with MMT, Average Product Slate

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TABLE A-1

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE I
METHANOL/COSOLVENTS (TBA, IBA, and IPA) IN ULR GASOLINE
1985 MARKET

	Price ($/m³)	Base Case Operation (m³/d)	4.75% Methanol/4.75% TBA			4.75% Methanol/4.75% IBA			4.75% Methanol/4.75% IPA		
				Differentials			Differentials			Differentials	
			Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)
Balance[1]											
Inputs											
Crude	250	14,120.0	13,831.0	(289.0)	(72.3)	13,774.0	(346.0)	(86.5)	13,754.0	(366.0)	(91.5)
Normal Butane	183	689.0	542.0	(147.0)	(26.9)	585.0	(104.0)	(19.0)	594.0	(95.0)	(17.4)
Isobutane	188	348.0	362.0	14.0	2.6	362.0	14.0	2.6	362.0	(14.0)	(2.6)
Oxygenate	0	0.0	345.0	345.0	0.0	345.0	345.0	0.0	345.0	345.0	0.0
Subtotal				(77.0)	(96.6)		(91.0)	(102.9)		(102.0)	(106.3)
Outputs											
LPG	154	270.0	243.0	(27.0)	(4.2)	240.0	(30.0)	(4.6)	238.0	(32.0)	(4.9)
HFO, 3% S[2]	195	265.0	236.0	(29.0)	(5.7)	230.0	(35.0)	(6.8)	228.0	(37.0)	(7.2)
Fuel Gas & Loss		63.0	42.0	(21.0)	0.0	37.0	(26.0)	0.0	30.0	(33.0)	0.0
Subtotal				(77.0)	(9.8)		(91.0)	(11.4)		(102.0)	(12.1)
Economics											
Variable Operating Costs											
Purchased Fuel	177	279.0	260.0	(19.0)	(3.4)	259.0	(20.0)	(3.5)	258.0	(21.0)	(3.7)
Utilities, Catalyst, Chemical & TEL, M$/d		62.4	60.1		(2.3)	59.9		(2.5)	59.9		(2.5)
Subtotal					(5.7)			(6.0)			(6.2)
Fixed & Capital Costs, M$/d		0.0	1.2		1.2	1.2		1.2	1.2		1.2
Revenue Change, M$/d					91.3			96.3			99.2
Oxygenate Economics											
Breakeven Value, $/m³					264.6			279.1			287.5
¢/L					26.5			27.9			28.8
Supply Cost, ¢/L					29.5			33.0			32.7
M$/d					101.7			113.9			112.7
Refiner's Margin, M$/d					(10.4)			(17.6)			(13.5)
¢/L Oxygenate					(3.0)			(5.1)			(3.9)
¢/L ULR Gasoline					(0.3)			(0.5)			(0.4)
Operational Changes											
Reformer Severity, RON		92.6	90.5			90.6			90.6		
Unleaded Regular RVP, psia		13.6	13.6			13.6			13.6		
Normal Butane in ULR Gasoline, Vol. %		12.4	8.7			10.0			10.4		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 960 m³/d.

TABLE A-2

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE I
METHANOL/ETHANOL, ETHANOL AND MTBE IN ULR GASOLINE
1985 MARKET

			5% Methanol/3% Ethanol			10% Ethanol			11% MTBE		
				Differentials			Differentials			Differentials	
Balance(1)	Price ($/m³)	Base Case Operation (m³/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)
Inputs											
Crude	250	14,120.0	13,876.0	(244.0)	(61.0)	13,761.0	(359.0)	(89.8)	13,583.0	(537.0)	(134.3)
Normal Butane	183	689.0	551.0	(138.0)	(25.3)	572.0	(117.0)	(21.4)	715.0	(16.0)	4.8
Isobutane	188	348.0	364.0	16.0	3.0	362.0	14.0	2.6	333.0	(15.0)	(2.8)
Oxygenate	0	0.0	290.0	290.0	0.0	363.0	363.0	0.0	399.0	399.0	0.0
Subtotal				(76.0)	(83.3)		(99.0)	(108.6)		(127.0)	(132.3)
Outputs											
LPG	154	270.0	243.0	(27.0)	(4.2)	239.0	(31.0)	(4.8)	227.0	(43.0)	(6.6)
HFO, 3% S(2)	195	265.0	240.0	(25.0)	(4.9)	229.0	(36.0)	(7.0)	215.0	(50.0)	(9.8)
Fuel Gas & Loss		63.0	39.0	(24.0)	0.0	29.0	(34.0)	0.0	29.0	(34.0)	0.0
Subtotal				(76.0)	(9.0)		(101.0)	(11.8)		(127.0)	(16.4)
Economics											
Variable Operating Costs											
Purchased Fuel	177	279.0	260.0	(19.0)	(3.4)	263.0	(16.0)	(2.8)	262.0	(17.0)	(3.0)
Utilities, Catalyst, Chemical & TEL, M$/d		62.4	60.6		(1.8)	60.2		(2.2)	59.6		(2.8)
Subtotal					(5.2)			(5.0)			(5.8)
Fixed & Capital Costs, M$/d		0.0	1.2		1.2	1.2		1.2	1.2		1.2
Revenue Change, M$/d					78.3			100.6			120.5
Oxygenate Economics											
Breakeven Value, $/m³					270.0			277.1			302.0
¢/L					27.0			27.7			30.2
Supply Cost, ¢/L					23.9			33.9			40.0
M$/d					69.3			123.1			159.2
Refiner's Margin, M$/d					9.0			(22.5)			(39.1)
¢/L Oxygenate					3.1			(6.2)			(9.8)
¢/L Unleaded Regular					0.2			(0.6)			(1.1)
Operational Changes											
Reformer Severity, RON		92.6	90.6			91.8			90.6		
Unleaded Regular RVP, psia		13.6	13.6			12.7			13.6		
Normal Butane In ULR Gasoline, Vol. %		12.4	9.1			10.0			12.8		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 960 m³/d.

TABLE A-3

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE I
METHANOL/TBA IN ULR GASOLINE WITH YIELD SENSITIVITY
1985 MARKET

			4.75% Methanol/4.75% TBA					
			No Yield Adjustment			Yield Adjustment(1)		
				Differentials			Differentials	
	Price ($/m³)	Reduced Lead Base Operation (m³/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)
Balance(2)								
Inputs								
Crude	250	14,120.0	13,831.0	(289.0)	(72.3)	13,948.0	(174.0)	(43.5)
Normal Butane	183	689.0	542.0	(147.0)	(26.9)	548.0	(141.0)	(25.8)
Isobutane	188	348.0	362.0	14.0	2.6	360.0	12.0	2.3
Oxygenate	0	0.0	345.0	345.0	0.0	355.0	355.0	0.0
Subtotal				(77.0)	(96.6)		52.0	(67.0)
Outputs								
LPG	154	270.0	243.0	(27.0)	(4.2)	249.0	(21.0)	(3.2)
ULR Gasoline	320	3,630.0	3,630.0	.0	.0	3,739.0	109.0	34.9
HFO, 2% S(3)	195	265.0	236.0	(29.0)	(5.7)	248.0	(17.0)	(3.3)
Fuel Gas & Loss		63.0	42.0	(21.0)	0.0	44.0	(19.0)	0.0
Subtotal				(77.0)	(9.8)		52.0	28.4
Economics								
Variable Operating Costs								
Purchased Fuel	177	279.0	260.0	(19.0)	(3.4)	261.0	(18.0)	(3.2)
Utilities, Catalyst, Chemical & TEL, M$/d		62.4	60.1		(2.3)	60.6		(1.8)
Subtotal					(5.7)			(5.0)
Fixed & Capital Costs, M$/d		0.0	1.2		1.2	1.2		1.2
Revenue Change, M$/d					91.3			99.2
Oxygenate Economics								
Breakeven Value, $/m³					264.6			279.4
¢/L					26.5			27.9
Supply Cost, ¢/L					29.5			29.5
M$/d					101.7			104.9
Refiner's Margin, M$/D					(10.4)			(5.7)
¢/L Oxygenate					(3.0)			(1.6)
¢/L Unleaded Regular					(0.3)			(0.2)

Notes: (1) ULR gasoline yield increased by 3% to offset decreased energy content.
(2) See Table 2 for full crude and product slate.
(3) HFO, 1.5% S set at 960 m³/d.

TABLE A-4

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE II
METHANOL/TBA IN ULR GASOLINE
APPROVED LEAD, WITH MMT, PRODUCT SLATE "A"

	Price ($/m³)	Base Case Operation (m³/d)	4.75% Methanol/4.75% TBA Operation (m³/d)	4.75% Methanol/4.75% TBA Differentials Yield (m³/d)	4.75% Methanol/4.75% TBA Differentials Costs (M$/d)	5% Methanol/3% TBA Operation (m³/d)	5% Methanol/3% TBA Differentials Yield (m³/d)	5% Methanol/3% TBA Differentials Costs (M$/d)	7% Methanol/3% TBA Operation (m³/d)	7% Methanol/3% TBA Differentials Yield (m³/d)	7% Methanol/3% TBA Differentials Costs (M$/d)
Balance(1)											
Inputs											
Crude	213	13,273.0	12,965.0	(308.0)	(65.6)	13,097.0	(176.0)	(37.5)	12,951.0	(322.0)	(68.6)
Normal Butane	154	590.0	417.0	(173.0)	(26.6)	382.0	(208.0)	(32.0)	395.0	(195.0)	(30.0)
Isobutane	166	332.0	335.0	3.0	0.5	335.0	3.0	0.5	336.0	4.0	0.7
Oxygenate	0	0.0	430.0	430.0	0.0	362.0	362.0	0.0	453.0	453.0	0.0
Subtotal				(48.0)	(91.7)		(19.0)	(69.0)		(60.0)	(98.0)
Outputs											
LPG	129	247.0	231.0	(16.0)	(2.1)	237.0	(10.0)	(1.3)	227.0	(20.0)	(2.6)
HFO, 3% S(2)	156	311.0	279.0	(32.0)	(5.0)	293.0	(18.0)	(2.8)	278.0	(33.0)	(5.1)
Fuel Gas & Loss		57.0	57.0	0.0	0.0	66.0	9.0	0.0	50.0	(7.0)	0.0
Subtotal				(48.0)	(7.1)		(19.0)	(4.1)		(60.0)	7.7)
Economics											
Variable Operating Costs											
Purchased Fuel	143	276.0	258.0	(18.0)	(2.6)	263.0	(13.0)	(1.9)	250.0	(26.0)	(3.7)
Utilities, Catalyst, Chemical & TEL, M$/d		56.6	52.7		(3.9)	53.3		(3.3)	52.6		(4.0)
Subtotal					(6.5)			(5.2)			(7.7)
Fixed & Capital Costs, M$/d		12.8	1.2		(11.6)	1.2		(11.6)	1.2		(11.6)
Revenue Change, M$/d					102.8			81.7			109.5
Oxygenate Economics											
Breakeven Value, $/m³					239.0			225.6			241.8
, ¢/L					23.9			22.6			24.2
Supply Cost, ¢/L					23.7			21.5			20.3
M$/d					101.9			77.8			92.0
Refiner's Margin, M$/d					(0.9)			3.9			17.6
¢/L Oxygenate					(0.2)			1.1			3.9
¢/L ULR Gasoline					0.0			0.1			0.4
Operational Changes											
Reformer Severity, RON		92.8	91.6			92.3			90.7		
Isomerization Capacity, m³/d		492.0	0.0			0.0			0.0		
Unleaded Regular RVP, psia		13.6	13.6			13.6			13.6		
Normal Butane in ULR Gasoline, Vol. %		13.4	8.1			7.6			7.4		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-5

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE II
METHANOL/IPA IN ULR GASOLINE
APPROVED LEAD, WITH MMT, PRODUCT SLATE "A"

	Price ($/m³)	Base Case Operation (m³/d)	4.75% Methanol/4.75% IPA Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	7% Methanol/3% IPA Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)								
Inputs								
Crude	213	13,273.0	12,873.0	(400.0)	(85.2)	12,871.0	(402.0)	(85.6)
Normal Butane	154	590.0	483.0	(107.0)	(16.5)	459.0	(131.0)	(20.2)
Isobutane	166	332.0	335.0	3.0	0.5	336.0	4.0	0.7
Oxygenate	0	0.0	430.0	430.0	0.0	453.0	453.0	0.0
Subtotal				(74.0)	(101.2)		(76.0)	(105.1)
Outputs								
LPG	129	247.0	224.0	(23.0)	(3.0)	224.0	(23.0)	(3.0)
HFO, 3% S(2)	156	311.0	270.0	(41.0)	(6.4)	270.0	(41.0)	(6.4)
Fuel Gas & Loss		57.0	47.0	(10.0)	0.0	45.0	(12.0)	0.0
Subtotal				(74.0)	(9.4)		(76.0)	(9.4)
Economics								
Variable Operating Costs								
Purchased Fuel	143	276	248.0	(28.0)	(4.0)	248.0	(28.0)	(4.0)
Utilities, Catalyst, Chemical & TEL, M$/d		56.6	52.4		(4.2)	52.3		(4.3)
Subtotal					(8.2)			(8.3)
Fixed & Capital Costs, M$/d		12.8	1.2		(11.6)	1.2		(11.6)
Revenue Change, M$/d					111.6			115.7
Oxygenate Economics								
Breakeven Value, $/m³					259.6			255.4
¢/L					26.0			25.5
Supply Cost, ¢/L					27.5			22.6
M$/d					118.3			102.4
Refiner's Margin, M$/d					(6.6)			13.3
¢/L Oxygenate					(1.5)			2.9
¢/L ULR Gasoline					(0.1)			0.3
Operational Changes								
Reformer Severity, RON		92.8	90.5			90.5		
Isomerization Capacity, m³/d		492.0	0.0			0.0		
Unleaded Regular RVP, psia		13.6	13.6			13.6		
Normal Butane in ULR Gasoline, Vol. %		13.4	9.4			8.9		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-6

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE II
METHANOL/IBA AND TOLUENE IN ULR GASOLINE
APPROVED LEAD, WITH MMT, PRODUCT SLATE "A"

	Price ($/m³)	Base Case Operation (m³/d)	4.75% Methanol/4.75% IBA			7% Methanol/3% IBA			Toluene		
				Differentials			Differentials			Differentials	
Balance(1)			Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)
Inputs											
Crude	213	13,273.0	12,902.0	(371.0)	(79.0)	12,938.0	(335.0)	(71.4)	12,809.0	(464.0)	(98.8)
Normal Butane	154	590.0	468.0	(122.0)	(18.8)	410.0	(180.0)	(27.7)	661.0	71.0	10.9
Isobutane	166	332.0	334.0	2.0	0.3	335.0	3.0	0.5	329.0	(3.0)	(0.5)
Oxygenate	0	0.0	430.0	430.0	0.0	453.0	453.0	0.0	333.0	333.0	0.0
Subtotal				(61.0)	(97.5)		(59.0)	(98.6)		(63.0)	(88.4)
Outputs											
LPG	129	247.0	228.0	(19.0)	(2.5)	228.0	(19.0)	(2.5)	230.0	(17.0)	(2.2)
HFO, 3% S(2)	156	311.0	273.0	(38.0)	(5.9)	277.0	(34.0)	(5.3)	264.0	(47.0)	(7.3)
Fuel Gas & Loss		57.0	53.0	(4.0)	0.0	51.0	(6.0)	0.0	58.0	1.0	0.0
Subtotal				(61.0)	(8.4)		(59.0)	(7.8)		(63.0)	(9.5)
Economics											
Variable Operating Costs											
Purchased Fuel	143	276.0	254.0	(22.0)	(3.1)	252.0	(24.0)	(3.4)	262.0	(14.0)	(2.0)
Utilities, Catalyst, Chemical & TEL, M$/d		56.6	52.5		(4.1)	52.6		(4.0)	52.5		(4.1)
Subtotal					(7.2)			(7.4)			(6.1)
Fixed & Capital Costs, M$/d		12.8	2.1		(10.7)	2.1		(10.7)	0.0		(12.8)
Revenue Change, M$/d					107.0			109.0			97.8
Oxygenate Economics											
Breakeven Value, $/m³					248.9			240.5			293.6
¢/L					24.9			24.1			29.4
Supply Cost, ¢/L					28.0			22.9			30.5
M$/d					120.4			103.7			101.6
Refiner's Margin, M$/d					(13.4)			5.2			(3.8)
¢/L Oxygenate					(3.1)			1.2			(1.1)
¢/L ULR Gasoline					(0.3)			0.1			(0.1)
Operational Changes											
Reformer Severity, RON		92.8	91.4			91.1			92.8		
Isomerization Capacity, m³/d		492.0	0.0			0.0			0.0		
Unleaded Regular RVP, psia		13.6	13.6			13.8			13.6		
Normal Butane in ULR Gasoline, Vol. %		13.4	9.1			7.8			13.9		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-7

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE II
METHANOL/ETHANOL, ETHANOL AND MTBE IN ULR GASOLINE
APPROVED LEAD, WITH MMT, PRODUCT SLATE "A"

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol			10% Ethanol			11% MTBE		
				Differentials			Differentials			Differentials	
			Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)
Balance(1)											
Inputs											
Crude	213	13,273.0	13,038.0	(235.0)	(50.1)	12,791.0	(482.0)	(102.7)	12,672.0	(601.0)	(128.0)
Normal Butane	154	590.0	422.0	(168.0)	(25.9)	531.0	(59.0)	(9.1)	623.0	33.0	5.1
Isobutane	166	332.0	336.0	4.0	0.7	331.0	(1.0)	(0.2)	304.0	(28.0)	(4.6)
Oxygenate	0	0.0	362.0	362.0	0.0	453.0	453.0	0.0	498.0	498.0	0.0
Subtotal				(37.0)	(75.3)		(89.0)	(111.9)		(98.0)	(127.6)
Outputs											
LPG	129	247.0	233.0	(14.0)	(1.8)	222.0	(25.0)	(3.2)	215.0	(32.0)	(4.1)
HFO, 3% S(2)	156	311.0	287.0	(24.0)	(3.7)	262.0	(49.0)	(7.6)	254.0	(57.0)	(8.9)
Fuel Gas & Loss		57.0	58.0	1.0	0.0	42.0	(15.0)	0.0	48.0	(9.0)	0.0
Subtotal				(37.0)	(5.6)		(89.0)	(10.9)		(98.0)	(13.0)
Economics											
Variable Operating Costs											
Purchased Fuel	143	276.0	257.0	(19.0)	(2.7)	253.0	(23.0)	(3.3)	251.0	(25.0)	(3.6)
Utilities, Catalyst, Chemical & TEL, M$/d		56.6	53.0		(3.6)	51.9		(4.7)	51.5		(5.1)
Subtotal					(6.3)			(8.0)			(8.7)
Fixed & Capital Costs, M$/d		12.8	1.2		(11.6)	1.2		(11.6)	1.2		(11.6)
Revenue Change, M$/d					87.6			120.6			134.8
Oxygenate Economics											
Breakeven Value, $/m³					242.1			266.3			270.8
¢/L					24.2			26.6			27.1
Supply Cost, ¢/L					21.9			33.0			27.6
M$/d					79.3			149.5			137.4
Refiner's Margin, M$/d					8.4			(28.9)			(2.6)
¢/L Oxygenate					2.3			(6.4)			(0.5)
¢/L ULR Gasoline					0.2			(0.6)			(0.1)
Operational Changes											
Reformer Severity, RON		92.8	91.6			91.6			90.2		
Isomerization Capacity, m³/d		492.0	0.0			0.0			0.0		
Unleaded Regular RVP, psia		13.6	13.6			13.6			13.6		
Normal Butane in ULR Gasoline, Vol. %		13.4	8.2			11.0			12.4		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-8

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE 1
METHANOL/TBA AND MTBE IN ULR GASOLINE
REDUCED LEAD, NO MMT, PRODUCT SLATE "A"

	Price ($/m³)	Base Case Operation (m³/d)	4.75% Methanol/4.75% TBA			5% Methanol/3% TBA			11% MTBE		
			Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)											
Inputs											
Crude	213	13,492.0	13,071.0	(421.0)	(89.7)	13,197.0	(295.0)	(62.8)	12,775.0	(717.0)	(152.7)
Normal Butane	154	504.0	346.0	(158.0)	(24.3)	312.0	(192.0)	(29.6)	551.0	47.0	7.2
Isobutane	166	305.0	317.0	12.0	2.0	319.0	14.0	2.3	308.0	3.0	0.5
Oxygenate	0	0.0	430.0	430.0	0.0	362.0	362.0	0.0	498.0	498.0	0.0
Subtotal				(137.0)	(112.0)		(111.0)	(90.1)		(169.0)	(145.0)
Outputs											
LPG	129	293.0	251.0	(42.0)	(5.4)	256.0	(37.0)	(4.8)	243.0	(50.0)	(6.5)
HFO, 3% S(2)	156	333.0	290.0	(43.0)	(6.7)	303.0	(30.0)	(4.7)	261.0	(72.0)	(11.2)
Fuel Gas & Loss		95.0	43.0	(52.0)	0.0	51.0	(44.0)	0.0	48.0	(47.0)	0.0
Subtotal				(137.0)	(12.1)		(111.0)	(9.5)		(169.0)	(17.7)
Economics											
Variable Operating Costs											
Purchased Fuel	143	327.0	283.0	(44.0)	(6.3)	289.0	(38.0)	(5.4)	283.0	(44.0)	(6.3)
Utilities, Catalyst, Chemical & TEL, M$/d		56.8	54.1		(2.7)	54.7		(2.1)	52.0		(4.8)
Subtotal					(9.0)			(7.5)			(11.1)
Fixed & Capital Costs, M$/d		39.2	21.2		(18.0)	21.4		(17.8)	18.4		(20.8)
Revenue Change, M$/d					126.9			106.0			159.2
Oxygenate Economics											
Breakeven Value, $/m³					295.1			292.7			319.7
¢/L					29.5			29.3			32.0
Supply Cost, ¢/L					23.7			21.5			27.6
M$/d					101.9			77.8			137.4
Refiner's Margin, M$/d					25.0			28.1			21.7
¢/L Oxygenate					5.8			7.8			4.4
¢/L ULR Gasoline					0.6			0.6			0.5
Operational Changes											
Reformer Severity, RON		99.2	94.5			94.9			95.5		
Isomerization Capacity, m³/d		985.0	951.0			961.0			697.0		
Unleaded Regular RVP, psia		13.6	13.6			13.6			13.6		
Normal Butane in ULR Gasoline, Vol. %		13.3	7.7			7.0			11.7		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-9

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE 1
METHANOL/ETHANOL, ETHANOL AND TOLUENE IN ULR GASOLINE
REDUCED LEAD, NO MMT, PRODUCT SLATE "A"

	Price ($/m³)	Base Case Operation (m³/d)	10% Ethanol			5% Methanol/3% Ethanol			Toluene		
				Differentials			Differentials			Differentials	
			Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)
Balance(1)											
Inputs											
Crude	213	13,492.0	12,900.0	(592.0)	(126.1)	13,146.0	(346.0)	(73.7)	12,819.0	(673.0)	(143.3)
Normal Butane	154	504.0	463.0	(41.0)	(6.3)	350.0	(154.0)	(23.7)	602.0	98.0	15.1
Isobutane	166	305.0	316.0	11.0	1.8	319.0	14.0	2.3	311.0	6.0	1.0
Oxygenate	0	0.0	453.0	453.0	0.0	362.0	362.0	0.0	400.0	400.0	0.0
Subtotal				(169.0)	(130.6)		(124.0)	(95.1)		(169.0)	(127.3)
Outputs											
LPG	129	293.0	245.0	(48.0)	(6.2)	253.0	(40.0)	(5.2)	247.0	(46.0)	(5.9)
HFO, 3% S(2)	156	333.0	273.0	(60.0)	(9.4)	298.0	(35.0)	(5.5)	265.0	(68.0)	(10.6)
Fuel Gas & Loss		95.0	34.0	(61.0)	0.0	46.0	(49.0)	0.0	40.0	(55.0)	0.0
Subtotal				(169.0)	(15.6)		(124.0)	(10.6)		(169.0)	(16.5)
Economics											
Variable Operating Costs											
Purchased Fuel	143	327.0	278.0	(49.0)	(7.0)	285.0	(42.0)	(6.0)	283.0	(44.0)	(6.3)
Utilities, Catalyst, Chemical & TEL, M$/d		56.8	52.8		(4.0)	54.5		(2.3)	53.4		(3.4)
Subtotal					(11.0)			(8.3)			(9.7)
Fixed & Capital Costs, M$/d		39.2	20.0		(19.2)	21.4		(17.8)	19.6		(19.6)
Revenue Change, M$/d					145.2			110.6			140.0
Oxygenate Economics											
Breakeven Value, $/m³					320.6			305.5			350.0
¢/L					32.1			30.5			35.0
Supply Cost, ¢/L					33.0			21.9			30.5
M$/d					149.5			79.3			122.0
Refiner's Margin, M$/d					(4.3)			31.3			18.0
¢/L Oxygenate					(0.9)			8.6			4.5
¢/L ULR Gasoline					(0.1)			0.7			0.4
Operational Changes											
Reformer Severity, RON		99.2	94.9			94.4			95.1		
Isomerization Capacity, m³/d		985.0	821.0			957.0			930.0		
Unleaded Regular RVP, psia		13.6	13.6			13.6			13.6		
Normal Butane in ULR Gasoline, Vol. %		13.3	10.9			8.0			14.7		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-10

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE 2
METHANOL/TBA IN ULR GASOLINE
REDUCED LEAD, WITH MMT, PRODUCT SLATE "A"

	Price ($/m³)	Base Case Operation (m³/d)	4.75% Methanol/4.75% TBA Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)					
Inputs					
Crude	213	13,371.0	13,037.0	(334.0)	(71.1)
Normal Butane	154	540.0	367.0	(173.0)	(26.6)
Isobutane	166	319.0	323.0	4.0	0.7
Oxygenate	0	0.0	430.0	430.0	0.0
Subtotal				(73.0)	(97.1)
Outputs					
LPG	129	266.0	244.0	(22.0)	(2.8)
HFO, 3% S(2)	156	321.0	287.0	(34.0)	(5.3)
Fuel Gas & Loss		88.0	71.0	(17.0)	0.0
Subtotal				(73.0)	(8.1)
Economics					
Variable Operating Costs					
Purchased Fuel	143	303.0	274.0	(29.0)	(4.1)
Utilities, Catalyst, Chemical & TEL, M$/d		55.9	52.7		(3.2)
Subtotal					(7.3)
Fixed & Capital Costs, M$/d		20.6	16.3		(4.3)
Revenue Change, M$/d					100.6
Oxygenate Economics					
Breakeven Value, $/m³					234.0
¢/L					23.4
Supply Cost, ¢/L					23.7
M$/d					101.9
Refiner's Margin, M$/d					(1.3)
¢/L Oxygenate					(0.3)
¢/L ULR Gasoline					0.0
Operational Changes					
Reformer Severity, RON		95.8	93.5		
Isomerization Capacity, m³/d		975.0	690.0		
Unleaded Regular RVP, psia		13.6	13.6		
Normal Butane in ULR Gasoline, Vol. %		13.6	7.8		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-11

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE 3
METHANOL/TBA IN ALL GASOLINE GRADES
REDUCED LEAD, NO MMT, PRODUCT SLATE "A"

	Price ($/m³)	Base Case Operation (m³/d)	4.75% Methanol/4.75% TBA Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)					
Inputs					
Crude	213	13,492.0	12,866.0	(626.0)	(133.3)
Normal Butane	154	504.0	249.0	(255.0)	(39.3)
Isobutane	166	305.0	322.0	17.0	2.8
Oxygenate	0	0.0	693.0	693.0	0.0
Subtotal				(171.0)	(169.8)
Outputs					
LPG	129	293.0	237.0	(56.0)	(7.2)
HFO, 3% S(2)	156	333.0	269.0	(64.0)	(10.0)
Fuel Gas & Loss		95.0	44.0	(51.0)	0.0
Subtotal				(171.0)	(17.2)
Economics					
Variable Operating Costs					
Purchased Fuel	143	327.0	268.0	(59.0)	(8.4)
Utilities, Catalyst, Chemical & TEL, M$/d		56.8	51.2		(5.6)
Subtotal					(14.0)
Fixed & Capital Costs, M$/d		39.2	14.7		(24.5)
Revenue Change, M$/d					191.1
Oxygenate Economics					
Breakeven Value, $/m³					275.8
¢/L					27.6
Supply Cost, ¢/L					23.7
M$/d					164.2
Refiner's Margin, M$/d					26.9
¢/L Oxygenate					3.9
¢/L Gasoline					0.4
Operational Changes					
Reformer Severity, RON		99.2	93.4		
Isomerization Capacity, m³/d		985.0	550.0		
RVP, psia					
Leaded Regular		13.6	13.6		
Unleaded Regular		13.6	13.6		
Unleaded Premium		13.6	13.6		
Normal Butane in Gasoline Pool, Vol.%		12.8	8.4		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-12

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE 4
METHANOL/COSOLVENTS (TBA AND ETHANOL) IN ULR GASOLINE
REDUCED LEAD, NO MMT, PRODUCT SLATE "B"

	Price ($/m³)	Base Case Operation (m³/d)	4.75% Methanol/4.75% TBA Operation (m³/d)	4.75% Methanol/4.75% TBA Differentials Yield (m³/d)	4.75% Methanol/4.75% TBA Differentials Costs (M$/d)	5% Methanol/3% TBA Operation (m³/d)	5% Methanol/3% TBA Differentials Yield (m³/d)	5% Methanol/3% TBA Differentials Costs (M$/d)	5% Methanol/3% Ethanol Operation (m³/d)	5% Methanol/3% Ethanol Differentials Yield (m³/d)	5% Methanol/3% Ethanol Differentials Costs (M$/d)
Balance(1)											
Inputs											
Crude	213	13,814.0	13,281.0	(533.0)	(113.5)	13,371.0	(443.0)	(94.4)	13,344.0	(470.0)	(100.1)
Normal Butane	154	482.0	308.0	(174.0)	(26.8)	270.0	(212.0)	(32.6)	314.0	(168.0)	(25.9)
Isobutane	166	250.0	304.0	54.0	9.0	324.0	74.0	12.3	319.0	69.0	11.5
Oxygenate	0	0.0	485.0	485.0	0.0	409.0	409.0	0.0	409.0	409.0	0.0
Subtotal				(168.0)	(131.4)		(172.0)	(114.7)		(160.0)	(114.5)
Outputs											
LPG	129	300.0	256.0	(44.0)	(5.7)	258.0	(42.0)	(5.4)	260.0	(40.0)	(5.2)
HFO, 3% S	156	376.0	315.0	(61.0)	(9.5)	321.0	(55.0)	(8.6)	319.0	(57.0)	(8.9)
Fuel Gas & Loss		145.0	82.0	(63.0)	0.0	70.0	(75.0)	0.0	82.0	(63.0)	0.0
Subtotal				(168.0)	(15.2)		(172.0)	(14.0)		(160.0)	(14.1)
Economics											
Variable Operating Costs											
Purchased Fuel	143	358.0	299.0	(59.0)	(8.4)	293.0	(65.0)	(9.3)	297.0	(61.0)	(8.7)
Utilities, Catalyst, Chemical & TEL, M$/d		57.6	53.9		(3.7)	55.0		(2.6)	54.1		(3.5)
Subtotal					(12.1)			(11.9)			(12.1)
Fixed & Capital Costs, M$/d		39.6	19.7		(19.9)	21.7		(17.9)	19.5		(20.1)
Revenue Change, M$/d					148.2			130.5			132.8
Oxygenate Economics											
Breakeven Value, $/m³					305.6			319.1			324.7
¢/L					30.6			31.9			32.5
Supply Cost, ¢/L					23.7			21.5			21.9
M$/d					114.9			87.9			89.6
Refiner's Margin, M$/d					33.3			42.6			43.2
¢/L Oxygenate					6.9			10.4			10.6
¢/L ULR Gasoline					0.7			0.8			0.8
Operational Changes											
Reformer Severity, RON		100.0	95.9			95.8			96.0		
Isomerization Capacity, m³/d		1,011.0	812.0			975.0			781.0		
Unleaded Regular RVP, psia		13.6	13.6			13.6			13.6		
Normal Butane in ULR Gasoline, Vol. %		12.7	7.6			6.7			8.0		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-13

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE 5
METHANOL/TBA AND MTBE IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, PRODUCT SLATE "B"

	Price ($/m³)	Base Case Operation (m³/d)	4.75% Methanol/4.75% TBA			5% Methanol/3% TBA			11% MTBE		
			Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)											
Inputs											
Crude	213	13,576.0	13,130.0	(446.0)	(95.6)	13,268.0	(308.0)	(65.6)	12,788.0	(788.0)	(167.8)
Normal Butane	154	525.0	252.0	(273.0)	(42.0)	199.0	(326.0)	(50.2)	580.0	55.0	8.5
Isobutane	166	323.0	281.0	(42.0)	(7.0)	313.0	(10.0)	(1.7)	223.0	(100.0)	(16.6)
Oxygenate	0	0.0	693.0	693.0	0.0	584.0	584.0	0.0	803.0	803.0	0.0
Subtotal				(68.0)	(144.0)		(60.0)	(117.5)		(30.0)	(176.0)
Outputs											
LPG	129	271.0	235.0	(36.0)	(4.6)	243.0	(28.0)	(3.6)	218.0	(53.0)	(6.8)
HFO, 3% S(2)	156	342.0	305.0	(37.0)	(5.8)	314.0	(28.0)	(4.4)	336.0	(6.0)	(0.9)
Fuel Gas & Loss		80.0	85.0	5.0	0.0	76.0	(4.0)	0.0	109.0	29.0	0.0
Subtotal				(68.0)	(10.4)		(60.0)	(8.0)		(30.0)	(7.8)
Economics											
Variable Operating Costs											
Purchased Fuel	143	308.0	268.0	(22.0)	(3.1)	281.0	(27.0)	(3.9)	289.0	(19.0)	(2.7)
Utilities, Catalyst, Chemical & TEL, M$/d		56.5	50.4		(6.1)	51.6		(4.9)	47.9		(8.6)
Subtotal					(9.2)			(8.8)			(11.3)
Fixed & Capital Costs, M$/d		28.7	11.0		(17.7)	12.5		(16.2)	7.9		(20.8)
Revenue Change, M$/d					160.5			134.4			200.3
Oxygenate Economics											
Breakeven Value, $/m³					231.7			230.2			249.5
¢/L					23.2			23.0			24.9
Supply Cost, ¢/L					23.7			21.5			27.6
M$/d					164.2			125.6			221.6
Refiner's Margin, M$/d					(3.7)			8.9			(21.3)
¢/L Oxygenate					(0.5)			1.5			(2.7)
¢/L Gasoline					(0.1)			0.1			(0.3)
Operational Changes											
Reformer Severity, RON		96.4	93.6			93.5			93.6		
Isomerization Capacity, m³/d		992.0	300.0			300.0			100.0		
RVP, psia											
Leaded Regular		13.6	13.6			13.6			13.6		
Unleaded Regular		13.6	13.6			13.6			13.6		
Unleaded Premium		13.6	13.6			13.6			13.6		
Normal Butane in Gasoline Pool, Vol.%		12.9	8.4			7.8			12.6		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-14

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE 5
METHANOL/ETHANOL AND ETHANOL IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, PRODUCT SLATE "B"

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol			10% Ethanol		
			Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)								
Inputs								
Crude	213	13,576.0	13,217.0	(359.0)	(76.5)	12,902.0	(674.0)	(143.6)
Normal Butane	154	525.0	258.0	(267.0)	(41.1)	441.0	(84.0)	(12.9)
Isobutane	166	323.0	301.0	(22.0)	(3.7)	245.0	(78.0)	(12.9)
Oxygenate	0	0.0	584.0	584.0	0.0	730.0	730.0	0.0
Subtotal				(64.0)	(121.2)		(106.0)	(169.4)
Outputs								
LPG	129	271.0	240.0	(31.0)	(4.0)	212.0	(59.0)	(7.6)
HFO, 3% S(2)	156	342.0	311.0	(31.0)	(4.8)	322.0	(20.0)	(3.1)
Fuel Gas & Loss		80.0	78.0	(2.0)	0.0	53.0	(27.0)	0.0
Subtotal				(64.0)	(8.8)		(106.0)	(10.7)
Economics								
Variable Operating Costs								
Purchased Fuel	143	308.0	282.0	(26.0)	(3.7)	283.0	(25.0)	(3.6)
Utilities, Catalyst, Chemical & TEL, M$/d		56.5	51.2		(5.3)	49.7		(6.8)
Subtotal					(9.3)			(10.4)
Fixed & Capital Costs, M$/d		28.7	11.7		(17.0)	14.7		(14.0)
Revenue Change, M$/d					138.4			183.1
Oxygenate Economics								
Breakeven Value, $/m³					237.0			250.8
¢/L					23.7			25.1
Supply Cost, ¢/L					21.9			33.0
M$/d					127.9			240.9
Refiner's Margin, M$/d					10.5			(57.8)
¢/L Oxygenate					1.8			(7.9)
¢/L Gasoline					0.1			(0.8)
Operational Changes								
Reformer Severity, RON		96.4	93.4			93.2		
Isomerization Capacity, m³/d		992.0	350.0			550.0		
RVP, psia								
Leaded Regular		13.6	13.6			13.6		
Unleaded Regular		13.6	13.6			13.6		
Unleaded Premium		13.6	13.6			13.6		
Normal Butane in Gasoline Pool, Vol.%		12.9	8.6			10.9		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-15

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE 6
METHANOL/TBA AND MTBE IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, PRODUCT SLATE "B" WITH FRONT END VOLATILITY INDEX SPECIFICATION

	Price ($/m³)	Base Case Operation (m³/d)	4.75% Methanol/4.75% TBA Operation (m³/d)	4.75% Methanol/4.75% TBA Differentials Yield (m³/d)	4.75% Methanol/4.75% TBA Differentials Costs (M$/d)	11% MTBE Operation (m³/d)	11% MTBE Differentials Yield (m³/d)	11% MTBE Differentials Costs (M$/d)
Balance(1)								
Inputs								
Crude	213	13,811.0	13,372.0	(439.0)	(93.5)	12,977.0	(834.0)	(177.6)
Normal Butane	154	326.0	0.0	(326.0)	(50.2)	318.0	(8.0)	(1.2)
Isobutane	166	327.0	336.0	9.0	1.5	247.0	(80.0)	(13.3)
Oxygenate	0	0.0	693.0	693.0	0.0	803.0	803.0	0.0
Subtotal				(63.0)	(142.2)		(119.0)	(192.2)
Outputs								
LPG	129	278.0	248.0	(30.0)	(3.9)	227.0	(51.0)	(6.0)
Normal Butane	154	0.0	27.0	27.0	4.2	0.0	0.0	0.0
HFO, 3% S(2)	156	366.0	321.0	(45.0)	(7.0)	295.0	(71.0)	(11.1)
Fuel Gas & Loss		76.0	61.0	(15.0)	0.0	79.0	3.0	0.0
Subtotal				(63.0)	(6.7)		(119.0)	(17.7)
Economics								
Variable Operating Costs								
Purchased Fuel	143	315.0	276.0	(39.0)	(5.6)	290.0	(25.0)	(3.6)
Utilities, Catalyst, Chemical & TEL, M$/d		57.3	51.9		(5.4)	49.2		(8.1)
Subtotal					(11.0)			(11.7)
Fixed & Capital Costs, M$/d		28.9	12.6		(16.3)	9.4		(19.5)
Revenue Change, M$/d					162.8			205.7
Oxygenate Economics								
Breakeven Value, $/m³					234.9			205.7
¢/L					23.5			25.6
Supply Cost, ¢/L					23.7			27.6
M$/d					164.2			221.6
Refiner's Margin, M$/d					(1.5)			(16.0)
¢/L Oxygenate					(0.2)			(2.0)
¢/L ULR Gasoline					0.0			(0.2)
Operational Changes								
Reformer Severity, RON		96.4	93.5			93.5		
Isomerization Capacity, m³/d		1,011.0	400.0			210.0		
RVP, psia								
Leaded Regular		13.6	11.7			11.6		
Unleaded Regular		12.2	11.5			11.8		
Unleaded Premium		11.5	12.2			11.8		
FEVI psia								
Leaded Regular		16.7	16.7			16.7		
Unleaded Regular		16.7	16.7			16.7		
Unleaded Premium		16.7	16.7			16.7		
Normal Butane in Gasoline Pool, Vol.%		10.2	4.7			9.2		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-16

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE 6
METHANOL/ETHANOL AND ETHANOL IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, PRODUCT SLATE "B" WITH FRONT END VOLATILITY INDEX SPECIFICATION

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol Operation (m³/d)	5% Methanol/3% Ethanol Differentials Yield (m³/d)	5% Methanol/3% Ethanol Differentials Costs (M$/d)	10% Ethanol Operation (m³/d)	10% Ethanol Differentials Yield (m³/d)	10% Ethanol Differentials Costs (M$/d)
Balance(1)								
Inputs								
Crude	213	13,811.0	13,512.0	(299.0)	(63.7)	13,257.0	(554.0)	(118.0)
Normal Butane	154	326.0	0.0	(326.0)	(50.2)	71.0	(255.0)	(39.3)
Isobutane	166	327.0	338.0	11.0	1.8	313.0	(14.0)	(2.3)
Oxygenate	0	0.0	584.0	584.0	0.0	730.0	730.0	0.0
Subtotal				(30.0)	(112.1)		(93.0)	(159.6)
Outputs								
LPG	129	278.0	252.0	(26.0)	(3.4)	240.0	(38.0)	(4.9)
Normal Butane	154	0.0	38.0	38.0	5.9	0.0	0.0	0.0
HFO, 3% S(2)	156	366.0	335.0	(31.0)	(4.8)	313.0	(53.0)	(8.3)
Fuel Gas & Loss		76.0	65.0	(11.0)	0.0	74.0	(2.0)	0.0
Subtotal				(30.0)	(2.3)		(93.0)	(13.2)
Economics								
Variable Operating Costs								
Purchased Fuel	143	315.0	279.0	(36.0)	(5.1)	278.0	(37.0)	(5.3)
Utilities, Catalyst, Chemical & TEL, M$/d		57.3	52.7		(4.6)	50.2		(7.1)
Subtotal					(9.7)			(12.4)
Fixed & Capital Costs, M$/d		28.9	13.3		(15.6)	8.6		(20.3)
Revenue Change, M$/d					135.1			179.1
Oxygenate Economics								
Breakeven Value, $/m³					231.3			245.4
¢/L					23.1			24.5
Supply Cost, ¢/L					21.9			33.0
M$/d					127.9			240.9
Refiner's Margin, M$/d					7.2			(61.8)
¢/L Oxygenate					1.2			(8.5)
¢/L ULR Gasoline					0.1			(0.8)
Operational Changes								
Reformer Severity, RON		96.4	93.5			93.5		
Isomerization Capacity, m³/d		1,011.0	450.0			150.0		
RVP, psia								
Leaded Regular		13.6	11.9			11.5		
Unleaded Regular		12.2	11.7			10.7		
Unleaded Premium		11.5	10.8			12.1		
FEVI, psia								
Leaded Regular		16.7	16.7			16.7		
Unleaded Regular		16.7	16.7			16.7		
Unleaded Premium		16.7	16.7			16.7		
Normal Butane in Gasoline Pool, %		10.2	4.7			5.9		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-17

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE 7
METHANOL/TBA AND MTBE IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, SUMMER PRODUCT SLATE

	Price ($/m³)	Base Case Operation (m³/d)	4.75% Methanol/4.75% TBA Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	5% Methanol/3% TBA Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	11% MTBE Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)											
Inputs											
Crude	213	13,981.0	13,370.0	(811.0)	(130.1)	13,575.0	(406.0)	(86.5)	12,835.0	(1,146.0)	(244.1)
Normal Butane	154	264.0	0.0	(264.0)	(40.7)	0.0	(264.0)	(40.7)	321.0	57.0	8.8
Isobutane	166	318.0	332.0	14.0	2.3	333.0	15.0	2.5	324.0	6.0	1.0
Oxygenate	0	0.0	726.0	726.0	0.0	612.0	612.0	0.0	841.0	841.0	0.0
Subtotal				(135.0)	(168.5)		(43.0)	(124.6)		(242.0)	(234.3)
Outputs											
LPG	129	288.0	254.0	(34.0)	(4.4)	262.0	(26.0)	(3.4)	237.0	(51.0)	(6.6)
Normal Butane	154	0.0	25.0	25.0	3.9	84.0	84.0	12.9	0.0	0.0	0.0
HFO, 3% S(2)	156	424.0	321.0	(103.0)	(16.1)	342.0	(82.0)	(12.8)	266.0	(158.0)	(24.6)
Fuel Gas & Loss		100.0	77.0	(23.0)	0.0	81.0	(19.0)	0.0	67.0	(33.0)	0.0
Subtotal				(135.0)	(16.6)		(43.0)	(3.2)		(242.0)	(31.2)
Economics											
Variable Operating Costs											
Purchased Fuel	143	317.0	274.0	(43.0)	(6.1)	281.0	(36.0)	(5.1)	261.0	(56.0)	(8.0)
Utilities, Catalyst, Chemical & TEL, M$/d		58.3	52.4		(5.9)	53.7		(4.6)	49.4		(8.9)
Subtotal					(12.0)			(9.7)			(16.9)
Fixed & Capital Costs, M$/d		29.0	12.9		(16.1)	14.2		(14.8)	9.0		(20.0)
Revenue Change, M$/d					180.0			146.0			240.0
Oxygenate Economics											
Breakeven Value, $/m³					247.9			238.6			285.4
¢/L					24.8			23.9			28.5
Supply Cost, ¢/L					23.7			21.5			27.6
M$/d					172.1			131.6			232.1
Refiner's Margin, M$/d					7.9			14.4			7.9
¢/L Oxygenate					1.1			2.4			0.9
¢/L Gasoline					0.1			0.2			0.1
Operational Changes											
Reformer Severity, RON		96.0	93.3			93.4			93.4		
Isomerization Capacity, m³/d		1,024.0	420.0			520.0			170.0		
RVP, psia											
Leaded Regular		11.5	11.5			11.5			11.5		
Unleaded Regular		11.5	11.5			11.5			11.5		
Unleaded Premium		11.5	11.5			11.5			11.5		
Normal Butane in Gasoline Pool, Vol. %		9.1	4.6			4.0			8.8		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-18

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE 7
METHANOL/ETHANOL AND ETHANOL IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, SUMMER PRODUCT SLATE

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol			10% Ethanol		
			Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)								
Inputs								
Crude	213	13,981.0	13,503.0	(478.0)	(101.8)	13,217.0	(764.0)	(162.7)
Normal Butane	154	264.0	0.0	(264.0)	(40.7)	12.0	(252.0)	(38.8)
Isobutane	166	318.0	333.0	15.0	2.5	334.0	16.0	2.7
Oxygenate	0	0.0	612.0	612.0	0.0	765.0	765.0	0.0
Subtotal				(115.0)	(140.0)		(235.0)	(198.9)
Outputs								
LPG	129	288.0	259.0	(29.0)	(3.7)	238.0	(50.0)	(6.5)
Normal Butane	154	0.0	21.0	21.0	3.2	0.0	0.0	0.0
HFO, 3% S(2)	156	424.0	334.0	(90.0)	(14.0)	305.0	(119.0)	(18.6)
Fuel Gas & Loss		100.0	83.0	(17.0)	0.0	34.0	(66.0)	0.0
Subtotal				(115.0)	(14.5)		(235.0)	(25.0)
Economics								
Variable Operating Costs								
Purchased Fuel	143	317.0	279.0	(38.0)	(5.4)	265.0	(52.0)	(7.4)
Utilities, Catalyst, Chemical & TEL, M$/d		58.3	53.1		(5.2)	52.1		(6.2)
Subtotal					(10.6)			(13.6)
Fixed & Capital Costs, M$/d		29.0	13.3		(15.7)	16.0		(13.0)
Revenue Change, M$/d					151.8			200.5
Oxygenate Economics								
Breakeven Value, $/m³					248.0			262.1
¢/L					24.8			26.2
Supply Cost, ¢/L					21.9			33.0
M$/d					134.0			252.5
Refiner's Margin, M$/d					17.8			(52.0)
¢/L Oxygenate					2.9			(6.8)
¢/L Gasoline					0.3			(0.7)
Operational Changes								
Reformer Severity, RON		96.0	93.5			93.3		
Isomerization Capacity, m³/d		1,024.0	450.0			660.0		
RVP, psia								
Leaded Regular		11.5	11.5			11.5		
Unleaded Regular		11.5	11.5			10.0		
Unleaded Premium		11.5	11.5			11.5		
Normal Butane in Gasoline Pool, Vol.%		9.1	4.8			5.0		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-19

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE 8
METHANOL/TBA AND MTBE IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, WINTER PRODUCT SLATE

	Price ($/m³)	Base Case Operation (m³/d)	4.75% Methanol/4.75% TBA			5% Methanol/3% TBA			11% MTBE		
			Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)											
Inputs											
Crude	213	13,362.0	12,946.0	(416.0)	(88.6)	13,098.0	(264.0)	(56.2)	12,636.0	(726.0)	(154.6)
Normal Butane	154	770.0	504.0	(266.0)	(41.0)	451.0	(319.0)	(49.1)	820.0	50.0	7.7
Isobutane	166	262.0	214.0	(48.0)	(8.0)	235.0	(27.0)	(4.5)	156.0	(106.0)	(17.6)
Oxygenate	0	0.0	680.0	680.0	0.0	573.0	573.0	0.0	787.0	787.0	0.0
Subtotal				(50.0)	(137.5)		(37.0)	(109.8)		5.0	(164.5)
Outputs											
LPG	129	254.0	220.0	(34.0)	(4.4)	227.0	(27.0)	(3.5)	209.0	(45.0)	(5.8)
HFO, 3% S(2)	156	330.0	297.0	(33.0)	(5.1)	310.0	(20.0)	(3.1)	328.0	(2.0)	(0.3)
Fuel Gas & Loss		110.0	127.0	17.0	0.0	120.0	10.0	0.0	162.0	52.0	0.0
Subtotal				(50.0)	(9.5)		(37.0)	(6.6)		5.0	(6.1)
Economics											
Variable Operating Costs											
Purchased Fuel	143	320.0	301.0	(19.0)	(2.7)	300.0	(20.0)	(2.9)	297.0	(23.0)	(3.3)
Utilities, Catalyst, Chemical & TEL, M$/d		55.2	49.1		(6.1)	50.2		(5.0)	46.4		(8.8)
Subtotal					(8.8)			(7.9)			(12.1)
Fixed & Capital Costs, M$/d		20.6	10.2		(10.4)	11.5		(9.1)	3.3		(17.3)
Revenue Change, M$/d					147.2			120.2			187.8
Oxygenate Economics											
Breakeven Value, $/m³					216.5			209.8			238.6
¢/L					21.7			21.0			23.9
Supply Cost, ¢/L					23.7			21.5			27.6
M$/d					161.2			123.2			217.2
Refiner's Margin, M$/d					(13.9)			(3.0)			(29.4)
¢/L Oxygenate					(2.0)			(0.5)			(3.7)
¢/L Gasoline					(0.2)			0.0			(0.4)
Operational Changes											
Reformer Severity, RON		96.2	93.3			93.5			94.5		
Isomerization Capacity, m³/d		974.0	250.0			330.0			0.0		
RVP, psia											
Leaded Regular		15.5	15.5			15.5			15.5		
Unleaded Regular		15.5	15.5			15.5			15.5		
Unleaded Premium		15.5	15.5			15.5			15.5		
Normal Butane in Gasoline Pool, Vol.%		16.4	11.9			11.3			16.1		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-20

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - CASE 8
METHANOL/ETHANOL AND ETHANOL IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, WINTER PRODUCT SLATE

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol			10% Ethanol		
			Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)								
Inputs								
Crude	213	13,362.0	13,043.0	(319.0)	(67.9)	12,772.0	(590.0)	(125.7)
Normal Butane	154	770.0	509.0	(261.0)	(40.2)	678.0	(92.0)	(14.2)
Isobutane	166	262.0	227.0	(35.0)	(5.8)	196.0	(66.0)	(11.0)
Oxygenate	0	0.0	573.0	573.0	0.0	716.0	716.0	0.0
Subtotal				(42.0)	(114.0)		(32.0)	(150.8)
Outputs								
LPG	129	254.0	224.0	(30.0)	(3.9)	212.0	(42.0)	(5.4)
HFO, 3% S(2)	156	330.0	305.0	(25.0)	(3.9)	308.0	(22.0)	(3.4)
Fuel Gas & Loss		110.0	123.0	13.0	0.0	142.0	32.0	0.0
Subtotal				(42.0)	(7.8)		(32.0)	(8.9)
Economics								
Variable Operating Costs								
Purchased Fuel	143	120.0	300.0	(20.0)	(2.9)	300.0	(20.0)	(2.9)
Utilities, Catalyst, Chemical & TEL, M$/d		55.2	49.8		(5.4)	47.2		(8.0)
Subtotal					(8.3)			(10.9)
Fixed & Capital Costs, M$/d		20.6	10.8		(9.8)	1.2		(19.4)
Revenue Change, M$/d					124.2			172.2
Oxygenate Economics								
Breakeven Value, $/m³					216.8			240.5
¢/L					21.7			24.1
Supply Cost, ¢/L					21.9			33.0
M$/d					125.5			236.3
Refiner's Margin, M$/d					(1.2)			(64.1)
¢/L Oxygenate					(0.2)			(8.9)
¢/L Gasoline					0.0			(.9)
Operational Changes								
Reformer Severity, RON		96.2	93.4			93.5		
Isomerization Capacity, m³/d		974.0	280.0			0.0		
RVP, psia								
Leaded Regular		15.5	15.5			15.5		
Unleaded Regular		15.5	15.5			15.5		
Unleaded Premium		15.5	15.5			15.5		
Normal Butane in Gasoline Pool, Vol.%		16.4	12.1			14.2		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE A-21

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - HYDROCRACKING REFINERY - CASE 9
METHANOL/COSOLVENT (TBA AND ETHANOL) IN ULR GASOLINE
APPROVED LEAD, WITH MMT, PRODUCT SLATE "A"

	Price ($/CM)	Base Case Operation (CM/d)	5% Methanol/3% TBA			5% Methanol/3% Ethanol		
			Operation (CM/d)	Differentials Yield (CM/d)	Differentials Costs (M$/d)	Operation (CM/d)	Differentials Yield (CM/d)	Differentials Costs (M$/d)
Balance(1)								
Inputs								
Crude	213	8,826.0	8,720.0	(106.0)	(22.6)	8,689.0	(137.0)	(29.2)
Normal Butane	154	229.0	102.0	(127.0)	(19.6)	128.0	(101.0)	(15.6)
Isobutane	166	30.0	38.0	8.0	1.3	39.0	9.0	1.5
Oxygenate	0	0.0	228.0	228.0	0.0	228.0	228.0	0.0
Subtotal				3.0	(40.8)		(1.0)	(43.2)
Outputs								
LPG	129	194.0	188.0	(6.0)	(0.8)	186.0	(8.0)	(1.0)
HFO, 3% S(2)	156	97.0	90.0	(7.0)	(1.1)	89.0	(8.0)	(1.2)
Fuel Gas & Loss		65.0	81.0	16.0	0.0	80.0	15.0	0.0
Subtotal				3.0	(1.9)		(1.0)	(2.3)
Economics								
Variable Operating Costs								
Purchased Fuel	143	450.0	438.0	(12.0)	(1.7)	434.0	(16.0)	(2.3)
Utilities, Catalyst, Chemical & TEL, M$/d		45.2	42.8		(2.4)	42.6		(2.6)
Subtotal					(4.1)			(4.9)
Fixed & Capital Costs, M$/d		14.6	10.4		(4.2)	10.2		(4.4)
Revenue Change, M$/d					47.3			50.2
Oxygenate Economics								
Breakeven Value, $/CM					207.3			220.4
¢/L					20.7			22.0
Supply Cost, ¢/L					21.5			21.9
M$/d					49.0			49.9
Refiner's Margin, M$/d					(1.8)			0.3
¢/L Oxygenate					(0.8)			0.1
¢/L Gasoline					(0.1)			0.0
Operational Changes								
Reformer Severity, RON		95.8	95.8			95.7		
Isomerization Capacity, CM/d		638.0	270.0			250.0		
Unleaded Regular RVP, psia		13.6	13.6			13.6		
Normal Butane in ULR Gasoline, Vol. %		13.1	7.0			8.0		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% set at 300 m^3/d.

TABLE A-22

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ONTARIO ECONOMICS - HYDROCRACKING REFINERY - CASE 10
METHANOL/COSOLVENTS (TBA AND ETHANOL) IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, PRODUCT SLATE "B"

	Price ($/CM)	Base Case Operation (CM/d)	4.75% Methanol/4.75% TBA			5% Methanol/3% TBA			5% Methanol/3% Ethanol		
			Operation (CM/d)	Differentials Yield (CM/d)	Differentials Costs (M$/d)	Operation (CM/d)	Differentials Yield (CM/d)	Differentials Costs (M$/d)	Operation (CM/d)	Differentials Yield (CM/d)	Differentials Costs (M$/d)
Balance(1)											
Inputs											
Crude	213	8,843.0	8,401.0	(442.0)	(94.1)	8,527.0	(316.0)	(67.3)	8,477.0	(366.0)	(78.0)
Normal Butane	154	196.0	49.0	(147.0)	(22.6)	10.0	(186.0)	(28.6)	46.0	(150.0)	(23.1)
Isobutane	166	0.0	34.0	34.0	5.6	30.0	30.0	5.0	26.0	26.0	4.3
Oxygenate	0	0.0	437.0	437.0	0.0	369.0	369.0	0.0	369.0	369.0	0.0
Subtotal				(118.0)	(111.1)		(103.0)	(91.0)		(121.0)	(96.7)
Outputs											
LPG	129	224.0	173.0	(51.0)	(6.6)	180.0	(44.0)	(5.7)	177.0	(47.0)	(6.1)
HFO, 3% S(2)	156	94.0	72.0	(22.0)	(3.4)	79.0	(15.0)	(2.3)	76.0	(18.0)	(2.8)
Fuel Gas & Loss		65.0	20.0	(45.0)	0.0	21.0	(44.0)	0.0	9.0	(56.0)	0.0
Subtotal				(118.0)	(10.0)		(103.0)	(8.0)		(121.0)	(8.9)
Economics											
Variable Operating Costs											
Purchased Fuel	143	476.0	410.0	(66.0)	(9.4)	423.0	(53.0)	(7.6)	426.0	(50.0)	(7.2)
Utilities, Catalyst, Chemical & TEL, M$/d		43.7	40.1		(3.6)	40.8		(2.9)	40.6		(3.1)
Subtotal					(13.0)			(10.5)			(10.3)
Fixed & Capital Costs, M$/d		24.6	15.3		(9.3)	15.4		(9.2)	15.4		(9.2)
Revenue Change, M$/d					123.5			102.6			107.3
Oxygenate Economics											
Breakeven Value, $/m^3					285.5			278.1			290.8
¢/L					28.3			27.8			29.1
Supply Cost, ¢/L					23.7			21.5			21.9
M$/d					103.6			79.3			80.8
Refiner's Margin, M$/d					19.9			23.3			26.5
¢/L Oxygenate					4.6			6.3			7.2
¢/L Gasoline					0.4			0.5			0.6
Operational Changes											
Reformer Severity, RON		99.8	94.2			94.8			94.3		
Isomerization Capacity, m^3/d		639.0	603.0			613.0			609.0		
RVP, psia											
Leaded Regular		13.6	13.6			13.6			13.6		
Unleaded Regular		13.6	13.6			13.6			13.6		
Unleaded Premium		13.6	13.6			13.6			13.6		
Normal Butane in Gasoline Pool, Vol.%		11.8	7.4			6.8			7.5		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 300 m^3/d.

TABLE B-1

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

BRITISH COLUMBIA ECONOMICS - CASE 11A-1
METHANOL/ETHANOL IN ULR GASOLINE
APPROVED LEAD, WITH MMT, PRODUCT SLATE "A"

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)					
Inputs					
Crude	212	13,270.0	13,058.0	(212.0)	(44.9)
Normal Butane	140	605.0	480.0	(125.0)	(17.5)
Isobutane	151	335.0	339.0	4.0	0.6
Oxygenate	0	0.0	274.0	274.0	0.0
Subtotal				(59.0)	(61.8)
Outputs					
LPG	117	246.0	229.0	(17.0)	(2.0)
HFO, 3% S(2)	156	311.0	289.0	(22.0)	(3.4)
Fuel Gas & Loss		71.0	51.0	(20.0)	0.0
Subtotal				(59.0)	(5.4)
Economics					
Variable Operating Costs					
Purchased Fuel	123	276.0	250.0	(26.0)	(3.2)
Utilities, Catalyst, Chemical & TEL, M$/d		56.9	55.0		(1.9)
Subtotal					(5.1)
Fixed & Capital Costs, M$/d		7.1	1.2		(5.9)
Revenue Change, M$/d					67.4
Oxygenate Economics					
Breakeven Value, $/m³					246.0
¢/L					24.6
Supply Cost, ¢/L					20.9
M$/d					57.3
Refiner's Margin, M$/d					10.2
¢/L Oxygenate					3.7
¢/L ULR Gasoline					0.3
Operational Changes					
Reformer Severity, RON		93.3	90.3		
Isomerization Capacity, m³/d		130.0	0.0		
Unleaded Regular RVP, psia		13.6	13.6		
Normal Butane in ULR Gasoline, Vol. %		13.2	8.2		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE B-2

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

BRITISH COLUMBIA ECONOMICS - CASE 11A
METHANOL/COSOLVENT (TBA AND ETHANOL) AND MTBE IN ULR GASOLINE
APPROVED LEAD, WITH MMT, PRODUCT SLATE "A"

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol			5% Methanol/3% TBA			11% MTBE		
				Differentials			Differentials			Differentials	
Balance(1)			Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)
Inputs											
Crude	212	13,273.0	13,038.0	(235.0)	(49.8)	13,097.0	(176.0)	(37.3)	12,672.0	(601.0)	(127.4)
Normal Butane	140	590.0	422.0	(168.0)	(23.5)	382.0	(208.0)	(29.1)	623.0	33.0	4.6
Isobutane	151	332.0	336.0	4.0	0.6	335.0	3.0	0.5	304.0	(28.0)	(4.2)
Oxygenate	0	0.0	362.0	362.0	0.0	362.0	362.0	0.0	498.0	498.0	0.0
Subtotal				(37.0)	(72.7)		(19.0)	(66.0)		(98.0)	(127.0)
Outputs											
LPG	117	247.0	233.0	(14.0)	(1.6)	237.0	(10.0)	(1.2)	215.0	(32.0)	(3.7)
HFO, 3% S(2)	156	311.0	287.0	(24.0)	(3.7)	293.0	(18.0)	(2.8)	254.0	(57.0)	(8.9)
Fuel Gas & Loss		57.0	58.0	1.0	0.0	66.0	9.0	0.0	48.0	(9.0)	0.0
Subtotal				(37.0)	(5.4)		(19.0)	(4.0)		(98.0)	(12.6)
Economics											
Variable Operating Costs											
Purchased Fuel	123	276.0	257.0	(19.0)	(2.3)	263.0	(13.0)	(1.6)	251.0	(25.0)	(3.1)
Utilities, Catalyst, Chemical & TEL, M$/d		56.6	53.0		(3.6)	53.3		(3.3)	51.5		(5.1)
Subtotal					(5.9)			(4.9)			(8.2)
Fixed & Capital Costs, M$/d		12.8	1.2		(11.6)	1.2		(11.6)	1.2		(11.6)
Revenue Change, M$/d					84.9			78.5			134.2
Oxygenate Economics											
Breakeven Value, $/m³					234.5			263.0			269.4
¢/L					23.5			26.3			26.9
Supply Cost, ¢/L					20.9			33.0			25.2
M$/d					75.7			149.5			125.5
Refiner's Margin, M$/d					9.2			(30.3)			8.7
¢/L Oxygenate					2.6			(6.7)			1.7
¢/L ULR Gasoline					0.2			(0.7)			0.2
Operational Changes											
Reformer Severity, RON		92.8	91.6			91.6			90.2		
Isomerization Capacity, m³/d		492.0	0.0			0.0			0.0		
Unleaded Regular RVP, psia		13.6	13.6			13.6			13.6		
Normal Butane in ULR Gasoline, Vol. %		13.4	8.2			11.0			12.4		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE B-3

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

BRITISH COLUMBIA ECONOMICS - CASE 11B
METHANOL/COSOLVENT (TBA AND ETHANOL) AND MTBE IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, PRODUCT SLATE "B"

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol			5% Methanol/3% TBA			11% MTBE		
			Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance[1]											
Inputs											
Crude	212	13,576.0	13,217.0	(359.0)	(76.1)	13,268.0	(308.0)	(65.3)	12,788.0	(788.0)	(167.1)
Normal Butane	140	525.0	258.0	(267.0)	(37.4)	199.0	(326.0)	(45.6)	580.0	55.0	7.7
Isobutane	151	323.0	301.0	(22.0)	(3.3)	313.0	(10.0)	(1.5)	223.0	(100.0)	(15.1)
Oxygenate	0	0.0	584.0	584.0	0.0	584.0	584.0	0.0	803.0	803.0	0.0
Subtotal				(64.0)	(116.8)		(60.0)	(112.4)		(30.0)	(174.5)
Outputs											
LPG	117	271.0	240.0	(31.0)	(3.6)	243.0	(28.0)	(3.3)	218.0	(53.0)	(6.2)
HFO, 3% S[2]	156	342.0	311.0	(31.0)	(4.8)	314.0	(28.0)	(4.4)	336.0	(6.0)	(0.9)
Fuel Gas & Loss		80.0	78.0	(2.0)	0.0	76.0	(4.0)	0.0	109.0	29.0	0.0
Subtotal				(64.0)	(8.5)		(60.0)	(7.6)		(30.0)	(7.1)
Economics											
Variable Operating Costs											
Purchased Fuel	123	308.0	282.0	(26.0)	(3.2)	281.0	(27.0)	(3.3)	289.0	(19.0)	(2.3)
Utilities, Catalyst, Chemical & TEL, M$/d		56.5	51.2		(5.3)	51.6		(4.9)	47.9		(8.6)
Subtotal					(8.5)			(8.2)			(10.9)
Fixed & Capital Costs, M$/d		28.7	11.7		(17.0)	12.5		(16.2)	7.9		(20.8)
Revenue Change, M$/d					133.8			129.2			199.1
Oxygenate Economics											
Breakeven Value, $/m³					229.2			221.3			247.9
¢/L					22.9			22.1			24.8
Supply Cost, ¢/L					20.9			19.8			25.2
M$/d					122.1			115.6			202.4
Refiner's Margin, M$/d					11.8			13.6			(3.3)
¢/L Oxygenate					2.0			2.3			(0.4)
¢/L Gasoline					0.2			0.2			0.0
Operational Changes											
Reformer Severity, RON		96.4	93.4			93.5			93.6		
Isomerization Capacity, m³/d		992.0	350.0			400.0			100.0		
RVP, psia											
Leaded Regular		13.6	13.6			13.6			13.6		
Unleaded Regular		13.6	13.6			13.6			13.6		
Unleaded Premium		13.6	13.6			13.6			13.6		
Normal Butane in Gasoline Pool, Vol.%		12.9	8.6			7.8			12.6		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE B-4

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

BRITISH COLUMBIA ECONOMICS - CASE 11C
METHANOL/ETHANOL IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, SUMMER PRODUCT SLATE

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)					
Inputs					
Crude	212	13,981.0	13,503.0	(478.0)	(101.3)
Normal Butane	140	264.0	0.0	(264.0)	(37.0)
Isobutane	151	318.0	333.0	15.0	2.3
Oxygenate	0	0.0	612.0	612.0	0.0
Subtotal				(115.0)	(136.0)
Outputs					
LPG	117	288.0	259.0	(29.0)	(3.4)
Normal Butane	140	0.0	21.0	21.0	2.9
HFO, 3% S(2)	156	424.0	334.0	(90.0)	(14.0)
Fuel Gas & Loss		100.0	83.0	(17.0)	0.0
Subtotal				(115.0)	(14.5)
Economics					
Variable Operating Costs					
Purchased Fuel	123	317.0	279.0	(38.0)	(4.7)
Utilities, Catalyst, Chemical & TEL, M$/d		58.3	53.1		(5.2)
Subtotal					(9.9)
Fixed & Capital Costs, M$/d		21.1	13.3		(7.8)
Revenue Change, M$/d					139.2
Oxygenate Economics					
Breakeven Value, $/m³					227.5
¢/L					22.7
Supply Cost, ¢/L					20.9
M$/d					127.9
Refiner's Margin, M$/d					11.3
¢/L Oxygenate					1.8
¢/L Gasoline					0.1
Operational Changes					
Reformer Severity, RON		96.0	93.5		
Isomerization Capacity, m³/d		1,024.0	450.0		
RVP, psia					
Leaded Regular		11.5	11.5		
Unleaded Regular		11.5	11.5		
Unleaded Premium		11.5	11.5		
Normal Butane in Gasoline Pool, Vol.%		9.1	4.8		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 780 m³/d.

TABLE C-1

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

PRAIRIE ECONOMICS - CASE 12A
METHANOL/COSOLVENT (TBA AND ETHANOL) AND MTBE IN ULR GASOLINE
APPROVED LEAD, WITH MMT, AVERAGE PRODUCT SLATE

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol			5% Methanol/3% TBA			11% MTBE		
				Differentials			Differentials			Differentials	
			Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)
Balance(1)											
Inputs											
Crude	207	14,000.0	13,838.0	(162.0)	(33.5)	13,868.0	(132.0)	(27.3)	13,600.0	(400.0)	(82.8)
Normal Butane	122	525.0	410.0	(115.0)	(14.0)	382.0	(143.0)	(17.4)	561.0	36.0	4.4
Isobutane	132	60.0	70.0	10.0	1.3	68.0	8.0	1.1	79.0	19.0	2.5
Oxygenate	0	0.0	256.0	256.0	0.0	256.0	256.0	0.0	352.0	352.0	0.0
Subtotal				(11.0)	(46.2)		(11.0)	(43.7)		7.0	(75.9)
Outputs											
LPG	100	242.0	229.0	(13.0)	(1.3)	231.0	(11.0)	(1.1)	218.0	(24.0)	(2.4)
HFO, 1.5% S(2)	142	937.0	952.0	15.0	2.1	950.0	13.0	1.8	974.0	37.0	5.3
Fuel Gas & Loss		(298.0)	(311.0)	(13.0)	0.0	(311.0)	(13.0)	0.0	(304.0)	(6.0)	0.0
Subtotal				(11.0)	0.8		(11.0)	0.7		7.0	2.9
Economics											
Variable Operating Costs											
Purchased Fuel	91	741.0	712.0	(29.0)	(2.6)	715.0	(26.0)	(2.4)	691.0	(50.0)	(4.6)
Utilities, Catalyst, Chemical & TEL, M$/d		73.1	71.7		(1.4)	71.8		(1.3)	70.4		(2.7)
Subtotal					(4.0)			(3.7)			(7.3)
Fixed & Capital Costs, M$/d		0.0	1.3		1.3	1.3		1.3	1.3		1.3
Revenue Change, M$/d					49.8			46.8			84.7
Oxygenate Economics											
Breakeven Value, $/m³					194.6			182.9			240.6
¢/L					19.5			18.3			24.1
Supply Cost, ¢/L					20.4			17.8			23.2
M$/d					52.2			45.6			81.7
Refiner's Margin, M$/d					(2.4)			1.3			3.0
¢/L Oxygenate					(0.9)			0.5			0.9
¢/L ULR Gasoline					(0.1)			0.0			0.1
Operational Changes											
Reformer Severity, RON		91.1	90.0			90.0			90.0		
Isomerization Capacity, m³/d		0.0	0.0			0.0			0.0		
Unleaded Regular RVP, psia		13.6	13.6			13.6			13.6		
Normal Butane in ULR Gasoline, Vol. %		14.7	9.1			8.3			13.3		

Notes: (1) See Table 2 for full crude and product slate.
(2) No 3.0% S HFO produced.

TABLE C-2

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

PRAIRIE ECONOMICS - CASE 12B
METHANOL/COSOLVENT (TBA AND ETHANOL) AND MTBE IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, AVERAGE PRODUCT SLATE

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol			5% Methanol/3% TBA			11% MTBE		
			Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)											
Inputs											
Crude	207	14,228.0	13,850.0	(378.0	(78.2)	13,917.0	(311.0)	(64.4)	13,282.0	(946.0)	(195.8)
Normal Butane	122	432.0	165.0	(267.0)	(32.6)	102.0	(330.0)	(40.3)	516.0	84.0	10.2
Isobutane	132	41.0	53.0	12.0	1.6	49.0	8.0	1.1	81.0	40.0	5.3
Oxygenate	0	0.0	583.0	583.0	0.0	583.0	583.0	0.0	802.0	802.0	0.0
Subtotal				(50.0)	(109.2)		(50.0)	(103.6)		(20.0)	(180.3)
Outputs											
LPG	100	297.0	254.0	(43.0)	(4.3)	259.0	(38.0)	(3.8)	220.0	(77.0)	(7.7)
HFO, 3% S(2)	142	911.0	951.0	40.0	5.7	945.0	34.0	4.8	1,003.0	92.0	13.1
Fuel Gas & Loss		(259.0)	(306.0)	(47.0)	0.0	(305.0)	(46.0)	0.0	(294.0)	(35.0)	0.0
Subtotal				(50.0)	1.4		(50.0)	1.0		(20.0)	5.4
Economics											
Variable Operating Costs											
Purchased Fuel	91	801.0	751.0	(50.0)	(4.6)	761.0	(40.0)	(3.6)	681.0	(120.0)	(10.9)
Utilities, Catalyst, Chemical & TEL, M$/d		68.8	64.7		(4.1)	65.0		(3.8)	61.9		(6.9)
Subtotal					(8.7)			(7.4)			(17.8)
Fixed & Capital Costs, M$/d		11.1	1.3		(9.8)	1.3		(9.8)	1.3		(9.8)
Revenue Change, M$/d					129.1			121.8			213.3
Oxygenate Economics											
Breakeven Value, $/m³					221.4			209.0			265.9
¢/L					22.1			20.9			26.6
Supply Cost, ¢/L					20.4			17.8			23.2
M$/d					118.9			103.8			186.1
Refiner's Margin, M$/d					10.1			18.1			27.2
¢/L Oxygenate					1.7			3.1			3.4
¢/L ULR Gasoline					0.1			0.2			0.4
Operational Changes											
Reformer Severity, RON		97.8	94.3			94.8			91.9		
Isomerization Capacity, m³/d		300.0	0.0			0.0			0.0		
RVP, psia											
Leaded Regular		13.6	13.6			13.6			13.6		
Unleaded Regular		13.6	13.6			13.6			13.6		
Unleaded Premium		13.6	13.6			13.6			13.6		
Normal Butane in Gasoline Pool, Vol.%		12.7	8.4			7.6			12.6		

Notes: (1) See Table 2 for full crude and product slate.
(2) No 3.0% S HFO produced.

TABLE C-3

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

PRAIRIE ECONOMICS - CASE 12C
METHANOL/ETHANOL IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, SUMMER PRODUCT SLATE

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)					
Inputs					
Crude	207	14,783.0	14,394.0	(389.0)	(80.5)
Normal Butane	122	140.0	0.0	(140.0)	(17.1)
Isobutane	132	44.0	72.0	28.0	3.7
Oxygenate	0	0.0	600.0	600.0	0.0
Subtotal				99.0	(93.9)
Outputs					
LPG	100	319.0	281.0	(38.0)	(3.8)
Normal Butane	122	0.0	168.0	168.0	20.5
HFO, 3% S(2)	142	885.0	857.0	(28.0)	(4.0)
Fuel Gas & Loss		(266.0)	(269.0)	(3.0)	0.0
Subtotal				99.0	12.7
Economics					
Variable Operating Costs					
Purchased Fuel	91	824.0	769.0	(55.0)	(5.0)
Utilities, Catalyst, Chemical & TEL, M$/d		70.4	66.8		(3.6)
Subtotal					(8.6)
Fixed & Capital Costs, M$/d		11.1	1.3		(9.8)
Revenue Change, M$/d					125.0
Oxygenate Economics					
Breakeven Value, $/m³					208.4
¢/L					20.8
Supply Cost, ¢/L					20.4
M$/d					122.4
Refiner's Margin, M$/d					2.6
¢/L Oxygenate					0.4
¢/L Gasoline					0.0
Operational Changes					
Reformer Severity, RON		97.9	95.9		
Isomerization Capacity, m³/d		300.0	0.0		
RVP, psia					
Leaded Regular		11.5	11.5		
Unleaded Regular		11.5	11.1		
Unleaded Premium		11.5	11.5		
Normal Butane in Gasoline Pool, Vol.%		8.8	4.0		

Notes: (1) See Table 2 for full crude and product slate.
(2) No 3.0% S HFO produced.

TABLE D-1

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

QUEBEC ECONOMICS - CASE 13A
METHANOL/COSOLVENT (TBA AND ETHANOL) AND MTBE IN ULR GASOLINE
APPROVED LEAD, WITH MMT, AVERAGE PRODUCT SLATE

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol			5% Methanol/3% TBA			11% MTBE		
				Differentials			Differentials			Differentials	
Balance(1)			Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)
Inputs											
Crude	215	11,598.0	11,490.0	(108.0)	(23.2)	11,511.0	(87.0)	(18.7)	11,226.0	(372.0)	(80.0)
Normal Butane	159	46.0	0.0	(46.0)	(7.3)	0.0	(46.0)	(7.3)	86.0	40.0	6.4
Oxygenate	0	0.0	226.0	226.0	0.0	226.0	226.0	0.0	311.0	311.0	0.0
Subtotal				72.0	(30.5)		93.0	(26.0)		(21.0)	(73.6)
Outputs											
LPG	146	211.0	208.0	(3.0)	(0.4)	209.0	(2.0)	(0.3)	197.0	(14.0)	(2.0)
Normal Butanes	159	0.0	64.0	64.0	10.2	89.0	89.0	14.2	0.0	0.0	0.0
HFO, 3% S(2)	152	1,693.0	1,700.0	7.0	1.1	1,697.0	4.0	0.6	1,681.0	(12.0)	(1.8)
Fuel Gas & Loss		(105.0)	(101.0)	4.0	0.0	(103.0)	2.0	0.0	(100.0)	5.0	0.0
Subtotal				72.0	10.8		93.0	14.5		(21.0)	(3.9)
Economics											
Variable Operating Costs											
Purchased Fuel	143	292.0	280.0	(12.0)	(1.7)	283.0	(9.0)	(1.3)	274.0	(18.0)	(2.6)
Utilities, Catalyst, Chemical & TEL, M$/d		49.1	47.5		(1.6)	47.7		(1.4)	46.0		(3.1)
Subtotal					(3.3)			(2.7)			(5.7)
Fixed & Capital Costs, M$/d		11.4	9.3		(2.1)	10.0		(1.4)	8.1		(3.3)
Revenue Change, M$/d					46.8			44.6			78.7
Oxygenate Economics											
Breakeven Value, $/m³					206.9			197.2			253.1
¢/L					20.7			19.7			25.3
Supply Cost, ¢/L					22.0			22.0			28.1
M$/d					49.7			49.7			87.4
Refiner's Margin, M$/d					(3.0)			(5.1)			(8.7)
¢/L Oxygenate					(1.3)			(2.3)			(2.8)
¢/L ULR Gasoline					(0.1)			(0.2)			(0.3)
Operational Changes											
Reformer Severity, RON		93.8	93.7			93.7			93.3		
Isomerization Capacity, m³/d		400.0	200.0			230.0			120.0		
Unleaded Regular RVP, psia		13.6	13.6			13.6			13.6		
Normal Butane in ULR Gasoline, Vol. %		13.0	7.9			6.2			12.2		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5 wt.% S set at 330 m³/d.

TABLE D-2

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

QUEBEC ECONOMICS - CASE 13B
METHANOL/COSOLVENT (TBA AND ETHANOL) AND MTBE IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, AVERAGE PRODUCT SLATE

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol			5% Methanol/3% TBA			11% MTBE		
				Differentials			Differentials			Differentials	
Balance(1)			Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)
Inputs											
Crude	215	11,658.0	11,377.0	(281.0)	(60.4)	11,417.0	(241.0)	(51.8)	11,010.0	(648.0)	(139.3)
Normal Butane	159	1.0	0.0	(1.0)	(0.2)	0.0	(1.0)	(0.2)	94.0	93.0	14.8
Oxygenate	0	0.0	390.0	390.0	0.0	390.0	390.0	0.0	537.0	537.0	0.0
Subtotal				108.0	(60.6)		148.0	(52.0)		(18.0)	(124.5)
Outputs											
LPG	146	221.0	203.0	(18.0)	(2.6)	205.0	(16.0)	(2.3)	189.0	(32.0)	(4.7)
Isobutane	172	0.0	134.0	134.0	23.0	172.0	172.0	29.6	0.0	0.0	0.0
HFO, 3% S(2)	152	1,700.0	1,699.0	(1.0)	(0.2)	1,700.0	0.0	0.0	1,704.0	4.0	0.6
Fuel Gas & Loss		(114.0)	(121.0)	(7.0)	0.0	(122.0)	(8.0)	0.0	(104.0)	10.0	0.0
Subtotal				108.0	20.3		148.0	27.2		(18.0)	(4.1)
Economics											
Variable Operating Costs											
Purchased Fuel	143	305.0	278.0	(27.0)	(3.9)	279.0	(26.0)	(3.7)	288.0	(17.0)	(2.4)
Utilities, Catalyst, Chemical & TEL, M$/d		48.2	45.2		(3.0)	45.6		(2.6)	42.6		(5.6)
Subtotal					(6.9)			(6.3)			(8.0)
Fixed & Capital Costs, M$/d		18.5	14.2		(4.3)	14.6		(3.9)	10.1		(8.4)
Revenue Change, M$/d					92.0			89.4			136.9
Oxygenate Economics											
Breakeven Value, $/m³					235.9			229.3			254.9
¢/L					23.6			22.9			25.5
Supply Cost, ¢/L					22.0			22.0			28.1
M$/d					85.8			85.8			150.9
Refiner's Margin, M$/d					6.2			3.6			(14.0)
¢/L Oxygenate					1.6			0.9			(2.6)
¢/L ULR Gasoline					0.1			0.1			(0.3)
Operational Changes											
Reformer Severity, RON		95.4	93.6			93.8			93.7		
Isomerization Capacity, m³/d		796.0	500.0			540.0			240.0		
RVP, psia											
Leaded Regular		13.6	13.6			13.6			13.6		
Unleaded Regular		13.6	13.6			13.6			13.6		
Unleaded Premium		13.6	13.6			13.6			13.6		
Normal Butane in Gasoline Pool, Vol.%		11.4	7.7			7.1			11.4		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 330 m³/d.

TABLE D-3

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

QUEBEC ECONOMICS - CASE 13C
METHANOL/ETHANOL IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, SUMMER PRODUCT SLATE

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)					
Inputs					
Crude	215	11,875.0	11,527.0	(348.0)	(74.8)
Oxygenate	0	0.0	410.0	410.0	0.0
Subtotal				62.0	(74.8)
Outputs					
LPG	146	236.0	210.0	(26.0)	(3.8)
Normal Butane	159	0.0	120.0	120.0	19.1
Isobutane	172	158.0	200.0	42.0	7.2
HFO, 3% S(2)	152	1,714.0	1,679.0	(35.0)	(5.3)
Fuel Gas & Loss		(98.0)	(137.0)	(39.0)	0.0
Subtotal				62.0	17.2
Economics					
Variable Operating Costs					
Purchased Fuel	143	316.0	284.0	(32.0)	(4.6)
Utilities, Catalyst, Chemical & TEL, M$/d		49.7	47.8		(1.9)
Subtotal					(6.5)
Fixed & Capital Costs, M$/d		18.7	17.4		(1.3)
Revenue Change, M$/d					99.8
Oxygenate Economics					
Breakeven Value, $/m³					243.4
¢/L					24.3
Supply Cost, ¢/L					22.0
M$/d					90.2
Refiner's Margin, M$/d					9.6
¢/L Oxygenate					2.3
¢/L ULR Gasoline					0.2
Operational Changes					
Reformer Severity, RON		95.7	92.0		
Isomerization Capacity, m³/d		814.0	774.0		
RVP, psia					
Leaded Regular		11.5	11.5		
Unleaded Regular		11.5	11.5		
Unleaded Premium		11.5	11.5		
Normal Butane in Gasoline Pool, Vol.%		8.3	4.2		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 330 m³/d.

TABLE E-1

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ATLANTIC ECONOMICS - CASE 14A
METHANOL/COSOLVENT (TBA AND ETHANOL) AND MTBE IN ULR GASOLINE
APPROVED LEAD, WITH MMT, AVERAGE PRODUCT SLATE

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol			5% Methanol/3% TBA			11% MTBE		
			Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)	Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)											
Inputs											
Crude	208	11,579.0	11,490.0	(89.0)	(18.5)	11,511.0	(68.0)	(14.1)	11,226.0	(353.0)	(73.4)
Normal Butane	155	50.0	0.0	(50.0)	(7.8)	0.0	(50.0)	(7.8)	86.0	36.0	5.6
Oxygenate	0	0.0	226.0	226.0	0.0	226.0	226.0	0.0	311.0	311.0	0.0
Subtotal				87.0	(26.3)		108.0	(21.9)		(6.0)	(67.8)
Outputs											
LPG	128	208.0	208.0	0.0	0.0	209.0	1.0	0.1	197.0	(11.0)	(1.4)
Normal Butane	155	0.0	64.0	64.0	9.9	89.0	89.0	13.8	0.0	0.0	0.0
HFO, 3% S(2)	147	1,691.0	1,700.0	9.0	1.3	1,697.0	6.0	0.9	1,681.0	(10.0)	(1.5)
Fuel Gas & Loss		(111.0)	(97.0)	(14.0)	0.0	(99.0)	12.0	0.0	(96.0)	15.0	0.0
Subtotal				87.0	11.2		108.0	14.8		(6.0)	(2.9)
Economics											
Variable Operating Costs											
Purchased Fuel	147	287.0	280.0	(7.0)	(1.0)	283.0	(4.0)	(0.6)	274.0	(13.0)	(1.9)
Utilities, Catalyst, Chemical & TEL, M$/d		49.2	47.5		(1.7)	47.7		(1.5)	46.0		(3.2)
Subtotal					(2.7)			(2.1)			(5.1)
Fixed & Capital Costs, M$/d		13.0	9.3		(3.7)	10.0		(3.0)	8.1		(4.9)
Revenue Change, M$/d					43.9			41.8			75.0
Oxygenate Economics											
Breakeven Value, $/m³					194.4			184.9			241.1
¢/L					19.4			18.5			24.1
Supply Cost, ¢/L					22.3			23.3			29.4
M$/d					50.4			52.7			91.4
Refiner's Margin, M$/d					(6.5)			(10.9)			(16.5)
¢/L Oxygenate					(2.9)			(4.8)			(5.3)
¢/L ULR Gasoline					(0.2)			(0.4)			(0.6)
Operational Changes											
Reformer Severity, RON		92.8	93.7			93.7			93.3		
Isomerization Capacity, m³/d		498.0	200.0			230.0			120.0		
Unleaded Regular RVP, psia		13.6	13.6			13.6			13.6		
Normal Butane in ULR Gasoline Vol.%		13.1	7.9			6.2			12.2		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 330 m³/d.

TABLE E-2

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ATLANTIC ECONOMICS - CASE 14B
METHANOL/COSOLVENT (TBA AND ETHANOL) AND MTBE IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, AVERAGE PRODUCT SLATE

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol			5% Methanol/3% TBA			11% MTBE		
				Differentials			Differentials			Differentials	
			Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)	Operation (m³/d)	Yield (m³/d)	Costs (M$/d)
Balance(1)											
Inputs											
Crude	208	11,658.0	11,377.0	(281.0)	(58.4)	11,417.0	(241.0)	(50.1)	11,010.0	(648.0)	(134.8)
Normal Butane	155	1.0	0.0	(1.0)	(0.2)	0.0	(1.0)	(0.2)	94.0	93.0	14.4
Oxygenate	0	0.0	390.0	390.0	0.0	390.0	390.0	0.0	537.0	537.0	0.0
Subtotal				108.0	(58.6)		148.0	(50.3)		(18.0)	(120.4)
Outputs											
LPG	128	221.0	203.0	(18.0)	(2.3)	205.0	(16.0)	(2.0)	189.0	(32.0)	(4.1)
Isburane	168	0.0	134.0	134.0	22.5	172.0	172.0	28.9	0.0	0.0	0.0
HFO, 3% S(2)	147	1,700.0	1,699.0	(1.0)	(0.1)	1,700.0	0.0	0.0	1,704.0	4.0	0.6
Fuel Gas & Loss		(114.0)	(121.0)	(7.0)	0.0	(122.0)	(8.0)	0.0	(104.0)	10.0	0.0
Subtotal				108.0	20.1		148.0	26.8		(18.0)	(3.5)
Economics											
Variable Operating Costs											
Purchased Fuel	147	305.0	278.0	(27.0)	(4.0)	279.0	(26.0)	(3.8)	288.0	(17.0)	(2.5)
Utilities, Catalyst, Chemical & TEL, M$/d		48.2	45.2		(3.0)	45.6		(2.6)	42.6		(5.6)
Subtotal					(7.0)			(6.4)			(8.1)
Fixed & Capital Costs, M$/d		18.5	14.2		(4.3)	14.6		(3.9)	10.1		(8.4)
Revenue Change, M$/d					89.9			87.5			133.4
Oxygenate Economics											
Breakeven Value, $/m³					230.6			224.2			248.3
¢/L					23.1			22.4			24.8
Supply Cost, ¢/L					22.3			23.3			29.4
M$/d					87.0			90.9			157.9
Refiner's Margin, M$/d					3.0			(3.4)			(24.5)
¢/L Oxygenate					0.8			(0.9)			(4.6)
¢/L ULR Gasoline					0.1			(0.1)			(0.5)
Operational Changes											
Reformer Severity, RON		95.4	93.6			93.8			93.7		
Isomerization Capacity, m³/d		796.0	500.0			540.0			240.0		
RVP, psia											
Leaded Regular		13.6	13.6			13.6			13.6		
Unleaded Regular		13.6	13.6			13.6			13.6		
Unleaded Premium		13.6	13.6			13.6			13.6		
Normal Butane in Gasoline Pool, Vol.%		11.4	7.7			7.1			11.4		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 330 m³/d.

TABLE E-3

ENERGY, MINES AND RESOURCES
EFFECT OF OXYGENATED FUELS ON REFINERIES

ATLANTIC ECONOMICS - CASE 14C
METHANOL/ETHANOL IN ALL GASOLINE GRADES
REDUCED LEAD, WITH MMT, SUMMER PRODUCT SLATE

	Price ($/m³)	Base Case Operation (m³/d)	5% Methanol/3% Ethanol Operation (m³/d)	Differentials Yield (m³/d)	Differentials Costs (M$/d)
Balance(1)					
Inputs					
Crude	208	11,875.0	11,527.0	(348.0)	(72.4)
Oxygenate	0	0.0	410.0	410.0	0.0
Subtotal				62.0	(72.4)
Outputs					
LPG	128	236.0	210.0	(26.0)	(3.3)
Normal Butane	155	0.0	120.0	120.0	18.6
Isobutane	168	158.0	200.0	42.0	7.1
HFO, 1% S(2)	147	1,714.0	1,679.0	(35.0)	(5.1)
Fuel Gas & Loss		(98.0)	(137.0)	(39.0)	0.0
Subtotal				62.0	17.2
Economics					
Variable Operating Costs					
Purchased Fuel	147	316.0	284.0	(32.0)	(4.7)
Utilities, Catalyst, Chemical & TEL, M$/d		49.7	47.8		(1.9)
Subtotal					(6.6)
Fixed & Capital Costs, M$/d		18.7	17.4		(1.3)
Revenue Change, M$/d					97.5
Oxygenate Economics					
Breakeven Value, $/m³					237.7
¢/L					23.8
Supply Cost, ¢/L					22.3
M$/d					91.4
Refiner's Margin, M$/d					6.0
¢/L Oxygenate					1.5
¢/L ULR Gasoline					0.1
Operational Changes					
Reformer Severity, RON		95.7	92.0		
Isomerization Capacity, m³/d		814.0	774.0		
RVP, psia					
Leaded Regular		11.5	11.5		
Unleaded Regular		11.5	11.5		
Unleaded Premium		11.5	11.5		
Normal Butane in Gasoline Pool, Vol.%		8.3	4.2		

Notes: (1) See Table 2 for full crude and product slate.
(2) HFO, 1.5% S set at 330 m³/d.